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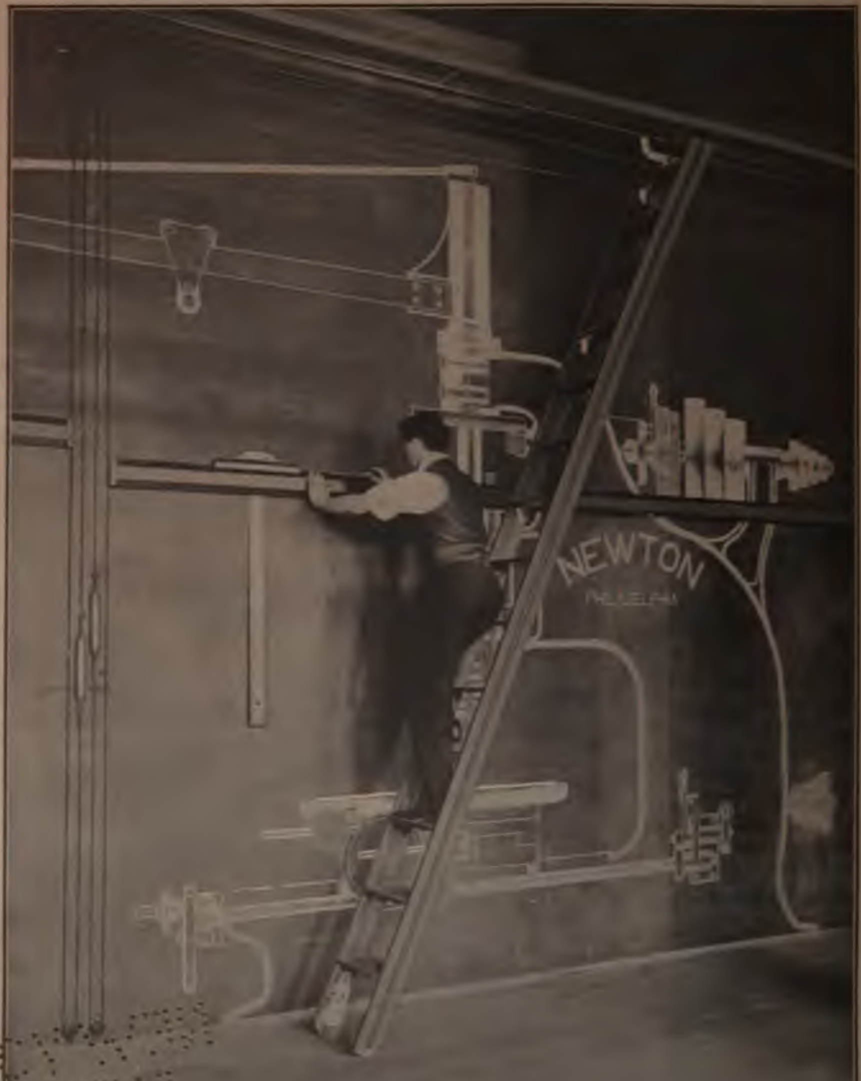

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OF

Modern Shop Practice

A Manual of

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SHOP PRACTICE, PATTERN MAKING, MACHINE DESIGN, FOUNDRY
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SHEET METAL WORK, STEAM, GAS AND OIL
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Grateful acknowledgment is here made also for the invaluable co-operation of the foremost engineering firms, in making these volumes thoroughly representative of the best and latest practice in the design and construction of steam and electrical machines and machine tools; also for the valuable drawings and data, suggestions, criticisms, and other courtesies.

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Introductory Note

THE successful education of the man in the shop is a question of vital importance. The difficulties under which he toils in his struggle for advancement, and his daily labor, render impossible the usual means of education, and prevent the attending of a resident technical school. Probably the most successful substitute for such a school is the correspondence method of instruction.

¶ Thousands of mechanics are improving their condition by devoting a half hour each day to systematic study under the direction of men who have had long experience in teaching, and in practical shop work. There are, however, many who cannot afford the time and expense necessary for a correspondence school course. For such the Cyclopedia of Modern Shop Practice is prepared.

¶ The instruction papers forming the Cyclopedia have been prepared especially for home study by acknowledged authorities, and represent the most careful study of actual shop needs and conditions. Although primarily intended for correspondence study, many are in use as text books by Harvard University, Columbia University, Lehigh University, Iowa State College, the University of Maine, the U. S. Government in its School of Submarine Defense, the Westinghouse Companies in their Shop School, and for reference in the leading colleges, shops and public libraries.

¶ Years of experience in the shop, laboratory, and class-room have been required in the preparation of the various sections of the Cyclopedia. Each section has been tested, by actual use, for its practical value to the man who desires to know the latest and best practice in the shop or engine room.

¶ Numerous examples for practice are inserted at intervals; these, with the test questions, help the reader to fix in mind the essential points, thus combining the advantages of a text book with a reference work.

¶ Grateful acknowledgment is due to the corps of writers and collaborators, who have prepared the many sections of this work. The hearty co-operation of these men—engineers of wide practical experience and acknowledged ability — has alone made these volumes possible.

¶ The Cyclopedia has been compiled with the idea of making it a work thoroughly technical yet easily comprehended by the man who has but little time in which to acquaint himself with the fundamental branches of practical engineering. If, therefore, it should benefit any of the large number of workers who need, yet lack, technical training, the editors will feel that its mission has been accomplished.

Contents

PART IV.

FORGING . . . . Page 11

ELECTRIC WELDING . . . . . " 107

SHEET METAL WORK . . . . . " 119

TINSMITHING . . . . . . " 271

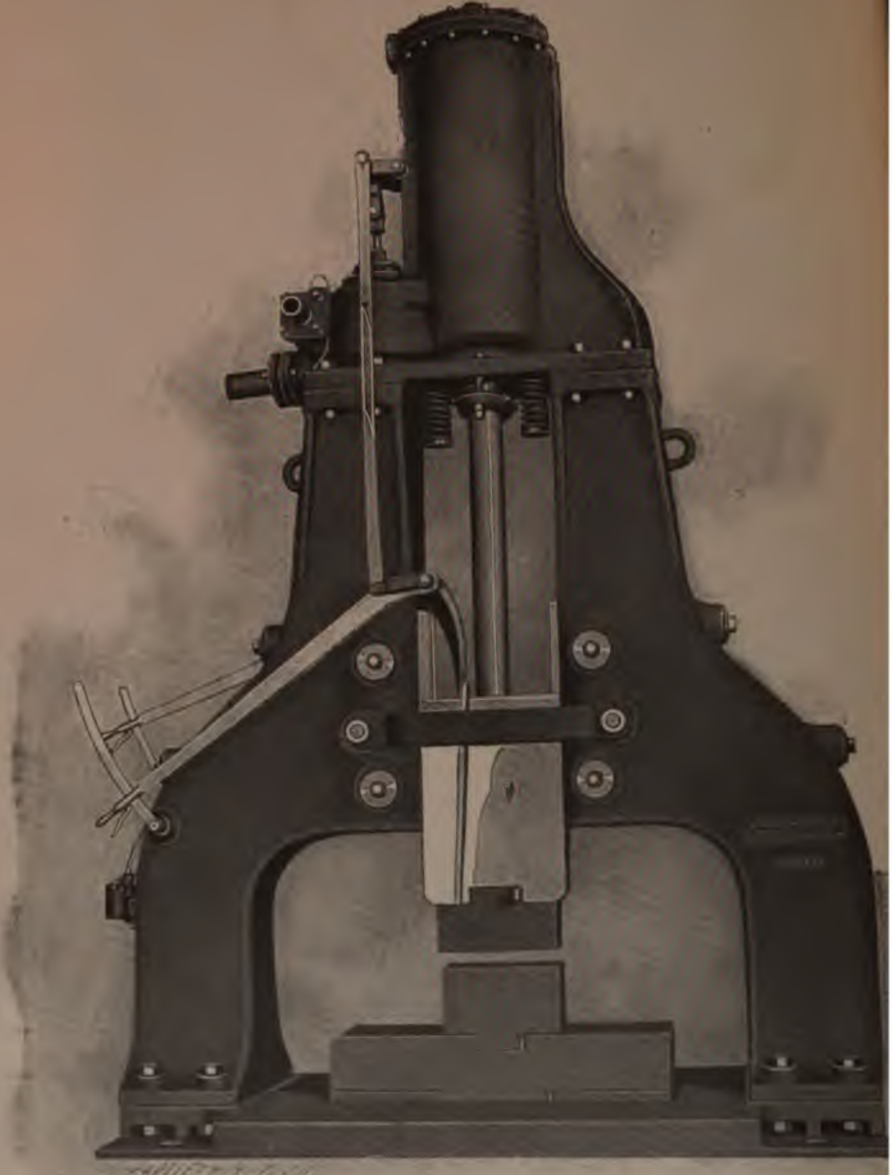
MECHANICAL DRAWING . . . . " 323

MECHANISM . . . . " 475

DRAFTING ROOM ORGANIZATION . . " 533

REVIEW QUESTIONS . . . . . " 543

INDEX . . . . " 549



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FORGING.

Forging in general treats of the hammering, working, or forming of heated metals.

The Materials upon which the work of forging or blacksmithing is done, are wrought iron and steel. As explained in "Metallurgy," wrought iron is an iron from which "the silicon phosphorus and most of the carbon has been removed." Steel usually contains some of the impurities that are characteristic of cast iron with the marked peculiarity of holding a varying percentage of carbon. Mild steels are so called on account of the small amount of carbon which they contain. As the percentage of carbon increases, it becomes more difficult to weld the metal. Greater care must also be used in heating lest the metal be burned and its strength destroyed. Until recently all heavy forgings involving welding, were made of wrought iron, but now it is customary to make most forgings of mild steel, particularly large ones, although wrought iron is somewhat more satisfactory where a great amount of welding is required.

These metals may be roughly divided into three general classes; although the division line may not be sharply drawn between any two classes, the classes being *Wrought Iron*, *Machine Steel* and *Tool Steel*. The characteristics and method of manufacture of the three metals are described in "Metallurgy." A rough distinction such as a blacksmith would use is about as follows: *Wrought Iron* has a fibrous structure with stringy streaks of slag running lengthwise of the bar giving it a decided fibre, similar to wood. *Machine Steel*, more properly described as mild steel, or sometimes called soft steel, has much the same properties as wrought iron excepting that it lacks the fibre and is somewhat stronger. *Tool Steel* differs from the other two materials in the fact that by suddenly cooling from a high heat it may be made very hard, or hardens, as the technical term is. Wrought iron or machine steel are not hardened by the same treatment. Tool steel is practically the same thing as wrought iron or machine steel with a small percentage of carbon added. In fact, either of the two metals may be turned into tool steel by the addition of carbon. This principle is used in case hardening. Norway iron or Swedish iron is a grade of very pure wrought iron containing little slag. It is more expensive than ordinary wrought iron. Refined iron is a grade of wrought iron not as good as Norway iron but better than ordinary iron. Norway iron costs about twice as much as machine steel, which is somewhat cheaper than wrought iron of almost any grade. Machine steel, made by both the open-hearth and Bessemer processes, is used for forging.

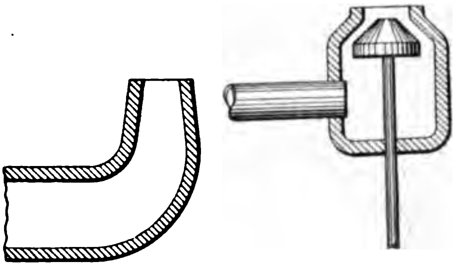


Fig. 1.

EQUIPMENT.

The equipment of the forge shop consists in general of a forge in which the metals are heated, an anvil for resting the metals on while hammering, and the various tools as described below for shaping and working.

The Forge. While forges or fires are of many shapes and sizes the principles of their construction remain the same. An ordinary blacksmith forge is a fireplace in the bottom of which there is a tuyere for admitting a blast of air to blow the fire. Where the air blast is furnished by a hand bellows, the pipe leading therefrom to the tuyere is open throughout. Where a power-driven blower furnishes the blast, there is a valve in the pipe for regulating the same.

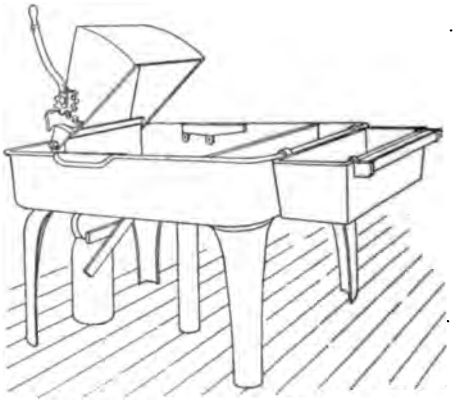


Fig. 2.

The usual form of tuyere consists of a single blast pipe, opening into the bottom of the fire pit. This may be a simple nozzle as in Fig. 1, with the blast regulated by a damper in the pipe; or, it may have a regulator at the mouth of the tuyere as shown. Sometimes the tuyere has several openings, and is then in the form of a grate. Whatever its form, it should be possible to clean it from below, in order that coal and clinkers falling into it may be removed.

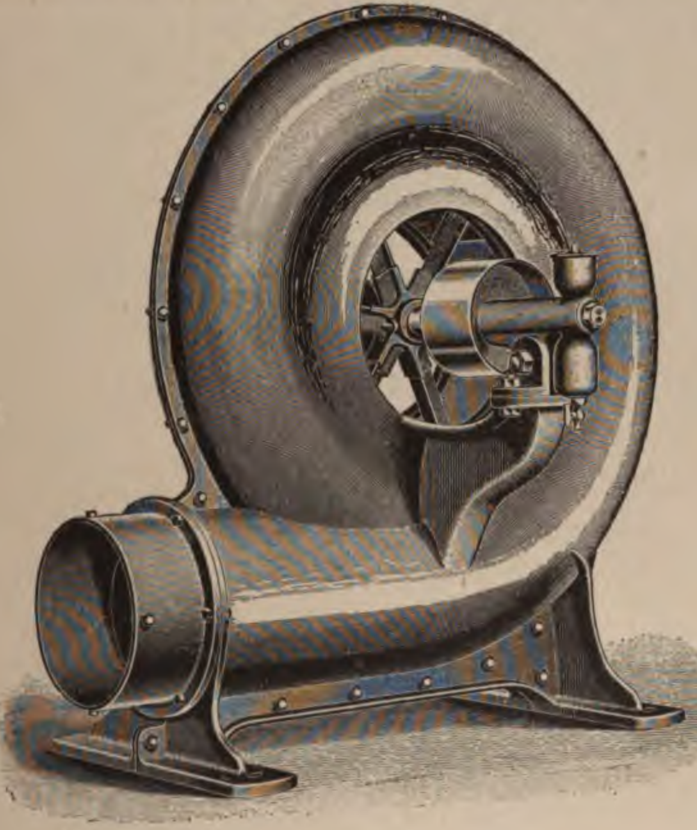


Fig. 3.

A modern type of forge is shown in Fig. 2. This is provided with a hood for carrying off the smoke. The pipe connected to the hood extends downward to an underground flue leading to an exhaust fan which draws out the air. The blast pipe is also underground, and a small pipe leads upward to the tuyere, the amount of blast admitted to the fire being regulated by a slide in this pipe. This system of underground piping is known as the "*Down Draft*" system.

In some shops no provision is made for carrying off the smoke, while in others hoods are placed above the forges and connected to overhead pipes, which may be either connected to an exhaust fan or led directly to the roof. The "Down Draft" system is the more modern and generally the best.

The Blast is furnished to the fires of a blacksmith shop by blowers of various kinds. For many years the ordinary bellows was used. This has been superseded by the fan blower which is now almost universally used, even for hand power.

Such a fan blower is shown in Fig. 3. It is formed of a thin cast-iron shell in which there are a set of rapidly revolving blades. These blades set up a current of air which presses against the side of the shell and escapes through the tangential opening. The pressure of the blast used for an open blacksmith fire varies from about 2 to 7 ounces per square inch. The lower pressure is used for a light fire and light work. The higher pressure is suitable for heavy classes of work.

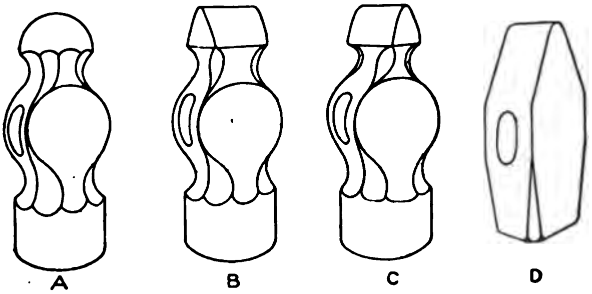


Fig. 4.

Hammers. Several kinds of hammers are used in a forge shop. The commonest shape is the *ball pene* shown at A, Fig. 4. Other kinds are the *straight pene* and *cross pene* illustrated at B and C. A *square faced* hammer sometimes called a blacksmith's hammer, is shown at D. This is occasionally used on tool work. Commonly a ball pene hammer of about a pound and a half weight is used.

In the fitting of the handle to the head great care should be taken. Hammer handles are made elliptical in cross section. The major axis of this ellipse should exactly coincide with that of the eye of the head. The reason is that the hand naturally grasps the handle so that its major axis lies in the direction of the line of motion. Hence, unless the handle is properly fitted in this particular, there will be constant danger of striking a glancing blow. The handle should also stand at right angles to a center line drawn from the ball of the pene to the face. The eye in the head is usually so set that the weight on the face side is greater than that on the pene. The effect of this is to so balance the tool that heavier and more accurate blows can be struck than if the weight were evenly balanced on each side of the eye.

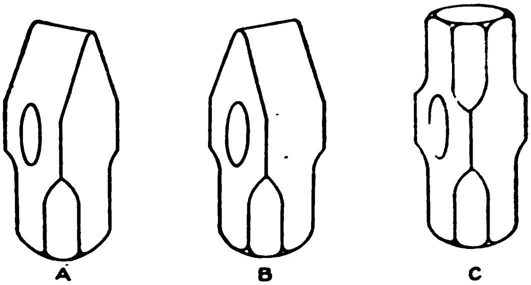


Fig. 5.

Sledges are heavier hammers used by the blacksmith's helper and vary in weight from five to twenty pounds. The three common shapes are shown in Fig. 5; A, B, and C being *cross pene*, *straight pene* and *double faced* sledges respectively. A sledge for common work ordinarily weighs about 12 pounds. Sledge handles are generally about 30 to 36 inches long, depending on the nature of the work to be done.

Anvils. Next to the hammer in importance is the anvil. This may be any block of metal upon which the piece to be shaped is laid. The anvil must be of such a weight that it can absorb the blows that are struck upon it without experiencing any perceptible motion in itself.

The ordinary anvil, Fig. 6, has remained unchanged in form for many hundreds of years. As now made, the body *a* is of wrought iron to which a face of hardened steel is welded. From one end there projects the horn *b*, and the overhang of the body at the other end *c*, is called the tail. At the bottom there are four projections *d*, called the feet, which serve to increase the base upon which the anvil rests as well as to afford the means for clamping it down into position. In the tail there is a square and a circular hole. The former is called the hardie hole, the latter the spud hole.

An anvil of this form serves for the execution of any work that may be desired.

Anvils are also made with a body of cast iron, to which a face of steel is welded.

The anvil should be placed upon the end of a heavy block of wood sunken into the ground to a depth of at least two feet, so that it may rest upon a firm but elastic foundation. As the anvil is subjected to constant vibrations, by the nature of the work, it is necessary that it should be firmly fastened to the block.

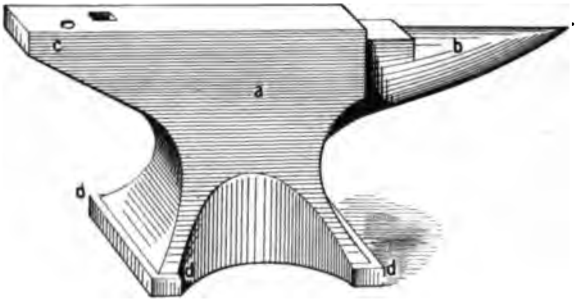


Fig. 6.

Anvils are classed and sold by weight. The weight is generally stamped on the side of the anvil. Three numbers are used. The first to the left shows the weight in cwt. of 112 pounds each. The middle number shows the additional quarters of cwt. and the right hand figure the number of odd pounds. For instance, an anvil marked 2-3-4 would weigh $2 \times 112 + \frac{3}{4}$ of $112 + 4$ lbs. $= 312$ lbs. and would be known as about a 300-pound anvil. Anvils are [illegible] made of special shapes, but the one here shown is the com [illegible]

Tongs. Next to the hammer and anvil in im usage are the tongs. They vary in size from those suit ing the smallest wires to those capable of handling ingots and bars of many tons in weight. The jaws are also adapted to fit over the piece to be handled and are of a great variety of shapes. As the requirements of each piece of work varies so much from that which precedes and follows it, it is customary for the blacksmith to dress his own tongs and adapt them, from time to time, to the work he has in hand. Comparatively few, therefore, of the various shapes of tongs found in shops are manufactured and for sale. A few of the general types and forms in common use are here given.

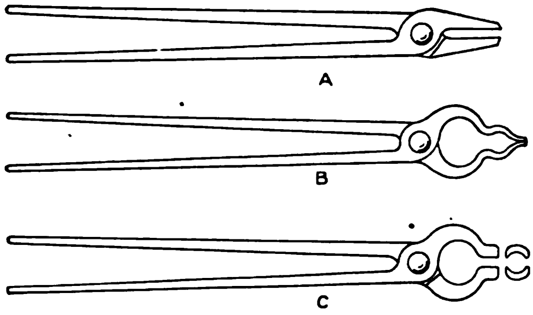


Fig. 7.

A, Fig. 7, shows a pair of *flat-jawed* tongs, the commonest shape used. B is a pair of *pick-up* tongs used for holding work while tempering, and picking up pieces of hot metal. C is a common shape used for holding both square and round iron, the jaws being bent to fit the stock in each case. A modification of this shape is also used for heavy steam hammer work. Tongs frequently have the jaws made in some special shape for a particular piece of work, the object always being to have the jaws grip the work as firmly as possible.

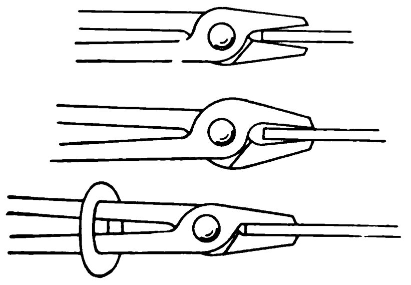


Fig. 8.

Fitting Tongs. Tongs must be always carefully fitted to the work. Tongs which take hold of the work as shown in Fig. 8. should not be used. The first pair shown have the jaws too close together, the second, too far apart. When properly fitted the jaws should touch the work throughout the entire length as shown in the lower sketch. To fit tongs the jaws are heated red hot, the piece to be held placed between them, and the jaws hammered down until touching their entire length. Tongs which do not fit the work perfectly should never, under any circumstances, be used. When in use on all but the smallest work, a link is driven over the handles to grip the tongs in position as shown.

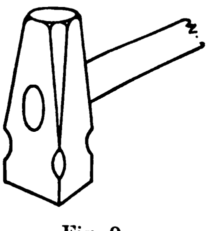


Fig. 9.

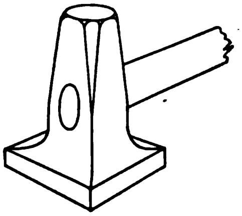


Fig. 10.

Set Hammers and Flatters are used for smoothing off flat work when finishing. The *set hammer*, Fig. 9, is used for working up into corners and narrow places. The *flatter*, Fig. 10, is used on wide flat surfaces. The face of the set hammer used on light work is generally about 1¼ inches square. That of the flatter about 2½ inches square, although the sizes vary depending upon the kind of work.

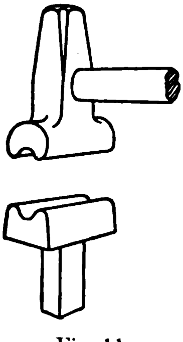


Fig. 11.

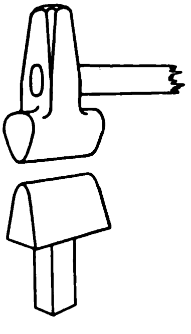


Fig. 12.

Swages, shown in Fig. 11, are used for finishing round and convex surfaces. The upper tool is known as the top swage and is provided with a handle. The lower one is the bottom swage and is held in place by a square stem or shank which extends downward and fits into the hardie hole of the anvil. Tools of this character should never be used on an anvil where they fit so tight that it is necessary to drive them into place. The swages shown here are used for round work. Swages are also made for octagonal, hexagonal and other shapes.

Fullers, used for working grooves or hollows into shape, are also made top and bottom as shown in Fig. 12. The top fuller is for finishing into round corners, around bosses, and on the inside of angles as illustrated later on. The fuller is also used to spread metal, when it is wished to work the metal only in one direction. The metal spreads at right angles to the working edge of the fuller.

Swage Blocks, a common sort of which is shown in Fig. 13, are used for a variety of purposes mostly for taking the place of bottom swages. These blocks are commonly made from cast iron and weigh about 150 pounds.

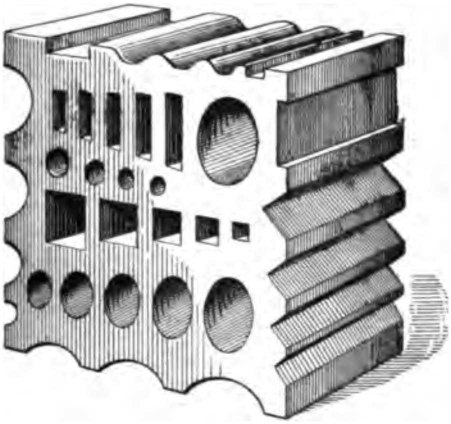


Fig. 13.

Other Tools. The tools used commonly are calipers, a carpenter's two-foot steel square, dividers, a rule, shovel, tongs, ladle, poker and a straight bar for loosening the fire. In addition to the ordinary calipers, a blacksmith usually has a pair of double calipers similar to those shown in Fig. 14. With these, two dimensions may be used, one side being set for the thickness, and the other for the width, of the material. When several measurements are to be made particularly on large work, a strip of light stock about ⅛-inch by 1 inch wide is used. The different dimensions are laid off on this with chalk or soapstone. In use the strip is held against the work and used in the same manner as a rule. A light rod having a small bent end, made by bending over about $\frac{1}{2}$ inch of stock at right angles, is also sometimes used, particularly when working under the steam hammer. The dimensions may be laid off from the inside of the hooked end. When in use the hooked end is pulled against the end of the material. Soap-stone crayon is ordinarily used for marking on iron. The marks do not burn off, but will not show at a red heat. Marks to show at a high heat must be made by nicking the corner of the bar with a chisel or by marking with the center punch. Another common way of making measurements on hot material is to lay off the different distances on the side of the anvil with chalk, the dimensions being laid off from one corner or end.

Fuel. The common fuel for small fires is "soft" or bituminous coal, coke for large fires and furnaces, and occasionally hard coal in small furnaces. The soft coal used is of a grade known as smithing coal. It should be very clean and free from impurities. A lump of good forge coal breaks easily with a crumbly looking fracture and the coal shows clean and bright on all faces. It will not break up into layers as "steaming" coal will, these seamy looking breaks being caused by the more or less earthy impurites. If forge coal splits and shows dull looking streaks or layers, it is poor coal. Good coal has little clinker and breaks easily. When used, the coal is dampened and kept wet before putting on the fire. It should be broken up fine before dampening, and not used in lumps.

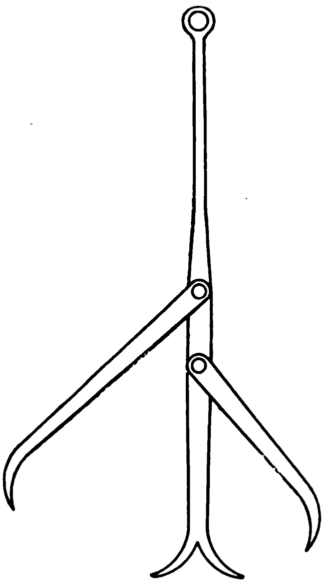


Fig. 11.

Fires. The fire must be carefully watched. It is very important that it should be in first class condition at all times for the work in hand. A certain depth of fire is always necessary. If the fire be too shallow, the cold blast will penetrate the fire in spots, making it impossible to heat the metal. There should be depth enough to the fire to prevent this. For small work there should be at least three or four inches of fire below the metal that is heating. There should also be thickness enough of fire above the work being heated to prevent the metal from losing heat to the outside air. The fire should be kept as small as possible to heat the work properly. As a general rule the fire will follow the blast. If the fire is wanted larger it may be made so by loosening the edges of the fire by a bar, allowing the blast to come through around the sides, causing the fire to spread. When a small fire is wanted the damp coal should be packed down tightly around the sides and the center of the fire loosened up slightly. For light work a small round fire is used. For heavier heating the fire is started by placing a large block on top of the tuyere, on each side of which green coal is packed down hard in the shape of an oblong mound. The block is then removed and the fire started in the hole left. These mounds are left undisturbed and fresh fuel is added to the fire in the shape of coke which has either been previously made by loosely banking a quantity of green coal over the fire and partially burning it to coke, or is bought ready made. With a small fire the fuel is constantly added around the sides where it is turned into coke. This coke is raked into the center of the fire as wanted and more coal added around the sides and patted down to keep the fire in shape.

Oxidizing and Reducing Fires. When too much blast is blown through the fire all the oxygen is not burned out of the air. This attacks the iron, forming a heavy coat of oxide, or scale, (the black scale which falls from heated iron). This sort of a fire is known as an oxidizing fire and should not be used when it is possible to avoid it. When just enough air is being admitted to keep the fire burning brightly and all of the oxygen is burned, the fire is in good condition for heating. Very little scale is formed and some of the scale already formed may even be turned back to iron. This sort of a fire is known as a reducing fire. In other words, when the fire is in condition to give oxygen to anything, it is an oxidizing fire. If in condition to take away oxygen, it is a reducing fire.

Banking the Fire. The fire may be kept for some time by placing a block of wood in the center and covering over with fresh coal.

Stock. Material from which forgings are ordinarily made comes to the forge shop in the shape of bars having uniform sections throughout; generally round, square, or rectangular in section, and varying from $\frac{1}{8}$-inch thick to 18 inches square. Heavier sizes may be had to order. Bars are ordinarily 12 to 20 feet in length. Thin stuff, $\frac{1}{8}$ of an inch or less in thickness, usually comes in strips of about 40 feet. This may be had from stock up to six or eight inches wide. Tool Steel also comes in bars generally about six or eight feet long. The ordinary sizes of tool steel stock are known as base sizes and the price is fixed on these base sizes. Stock of a larger or smaller size than the base sizes is generally charged for at an increase in price. Thus inch square tool steel, which is a base size, is worth in certain grades about 14 cents a pound. Steel of exactly the same grade and character, $\frac{3}{16}$ of an inch square, costs about 18 cents.

WELDING.

If a piece of steel or iron be heated, as the temperature is raised the metal becomes softer. Finally a heat is reached, called the welding heat, at which the metal is so soft that if two pieces similarly heated be placed in contact, they will stick. If the pieces so heated be placed together and hammered, they may be joined into one piece. This process is known as welding. The greatest difficulty in welding is to heat properly, which must be done evenly and cleanly. If the temperature is raised too high, the iron will burn, throwing off bright star-like sparks. If the temperature be too low, the pieces will not stick to each other. The proper heat can only be determined by experimenting, which may be easily done by doubling over a piece of scrap iron for two or three inches and welding into a solid piece.

When heating wrought iron and mild steel, as the welding heat is reached, small particles of the metal are melted and blown upward from the fire by the blast. As these small particles come in contact with the air they burn and form small explosive sparks, like little white stars. Whenever these sparks are seen coming from the fire, it is a sure indication that the iron is burning. These sparks are sometimes used as a sort of an indication of the welding heat. The only sure way of determining the heat is by the appearance of the heated iron, which might be described as sort of creamy white. The welding heat is sometimes described as a white heat. This is not correct, as iron or steel is never raised to a white heat even when melted. This may be easily proved by comparing a piece of wrought iron at welding heat, with an ordinary arc lamp. When two pieces of metal are welded together there must be nothing between them. Heated iron or steel is always covered with scale (iron oxide). This scale, if allowed to stay on the surfaces to be joined, will prevent a good weld. It is necessary when welding, to heat the iron or steel to a high enough temperature to melt this scale and when the two pieces are put together, if the joint or scarf is properly made, most of this melted scale is easily forced from between the two pieces, leaving the clean surfaces of the metal in contact. This scale only melts at a very high heat, much higher than the heat at which it would be possible to weld the iron could it be kept free from scale.

Fluxes. These are used to lower the melting point of the scale. The flux is sprinkled on the surfaces to be joined just before the metal reaches the welding heat. The metal is then put back into the fire, raised to the welding heat and the weld made as usual. The scale is acted upon by the flux and melts at a lower heat than when no flux is used. As the flux melts it spreads, or runs, over the hot metal and forms a sort of protective covering, which, by keeping out the air, prevents to a large extent, the formation of more scale. The flux in no way acts as a cement or glue to stick the pieces together, but merely helps to melt off the scale already formed, and prevents the formation of more.

Sand and Borax. These substances are common fluxes. Sand may be used when welding wrought iron and machine steel; borax in place of sand for fine work and when welding tool steel. Borax is a better flux as it melts at a lower temperature than sand, and thus makes welding possible at a lower heat. Borax and salammoniac (ammonium-chloride) are sometimes mixed and used as a welding compound, or flux, the proportion being about four parts borax to one part salammoniac. This mixture is also a good flux for brazing. Borax contains a large amount of water which makes it boil and foam when melting and in this condition is very liable to drop away from the heating metal. If borax be heated red hot and allowed to cool, the water is driven off and the borax left in a glass like condition.

Borax treated this way and then powdered, is the best for welding, as it melts and sticks to the metal without any boiling.

Welding Compounds are fluxes serving the same purpose as sand or borax. Some of the better ones use borax as a basis. Some of these compounds are first class for their purpose and others are not as good, being simply intended as cheap substitutes for borax.

Fagot Weld. This is made by simply placing two or more pieces on top of each other and welding them in a lump or slab. Scrap iron is worked up in this way by making a pile six or eight inches square and eighteen inches or two feet long on a board, such as shown in Fig. 15. This pile is bound together with wires and placed in a furnace, fluxed with sand, and welded into a solid lump under a steam hammer. These lumps are afterwards worked out in bars or slabs by rolling or hammering. When a large piece is wanted, two or more of these bars are placed together and welded.

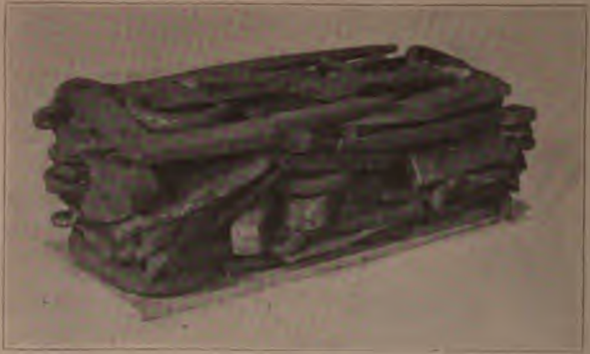


Fig. 15.

Scarfing. For most welding the ends of the pieces to be joined must be so shaped that when welded they will make a smooth joint. This shaping of the ends is known as *scarfing*, and the shaped end is called a *scarf*. The scarfed ends should not fit tightly before welding, but should be so shaped that they touch in the center of the joint, leaving the sides somewhat open. In this way when the weld is made, the melted scale is forced from between the pieces. If the scarfs were made to touch on the edge of the joint, leaving the center hollow, the scale not having a chance to escape, would be held in the center of the joint, leaving a weak place, and making a bad weld.

Lap Weld. This is the common weld used for joining flat bars together. The ends to be welded are scarfed or shaped as shown in Fig. 16. In preparing, the ends of the pieces to be welded should be first upset until they are considerably thicker than the rest of the bar. This is done to allow for the iron that burns off, or is lost by scaling, and also to allow for the hammering when welding the pieces together. To make a proper weld the joint should be well hammered, and as this reduces the size of the iron at that point, the pieces must be upset to allow for this reduction in size. For light work the scarfing may be done with a hand hammer. For heavy work a fuller and sledge should be used. After upsetting on light work, the end to be scarfed is roughly shaped with the pene end of the hammer as illustrated in Fig. 17, the final finishing being done with the flat face of the hammer.

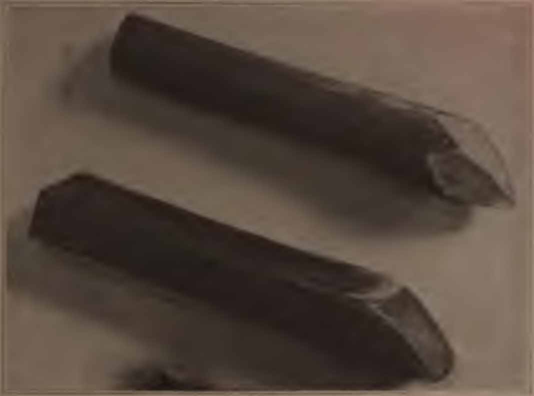


Fig. 16.

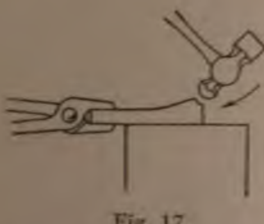


Fig. 17.

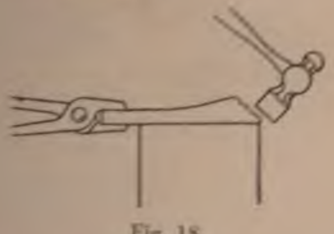


Fig. 18.

For this work (finishing the edge of the scarf) as well as all pointed work, the end of the bar should be brought to the extreme edge of the anvil in the manner indicated in Fig. 18. In this way a hard blow may be struck with the center of the face of the hammer without danger of striking the hammer on the anvil. For all ordinary lap welding the length of the scarf may be about 1½ times the thickness of the bar Thus on a bar ½-inch thick, the scarf will be about ¾ of an inch long. The width of the end, Fig. 16, should be slightly less than the width of the bar. In welding the pieces together the the first piece held by the helper should be placed scarf side up on the anvil and the second piece laid on top, scarf side down, overlapping them to about the amount shown in Fig. 19. As it is generally somewhat difficult to lay the top piece directly in place, it should be steadied by resting lightly against the corner of the anvil and thus "steered" into place.

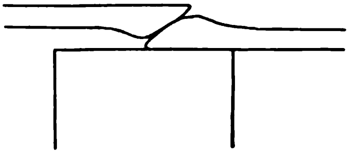


Fig. 19.

Round Lap Weld. This is the weld used to join round bars end to end to form a continuous bar. All the precautions regarding the scarf, etc., used for making the lap weld should be taken with this as well. The general shape of the scarf is shown in Fig. 16. It will be noticed that the end is hammered to a sharp point. If the scarf be made with a flat or chisel-shaped end similar to the flat lap weld, the corners will project beyond the sides of the bar in welding and cause considerable trouble, as it will then be necessary to work entirely around the bar before the joint be closed down. With a pointed scarf the weld may be frequently made by hammering on two sides only. This is not so important when welding between swages.

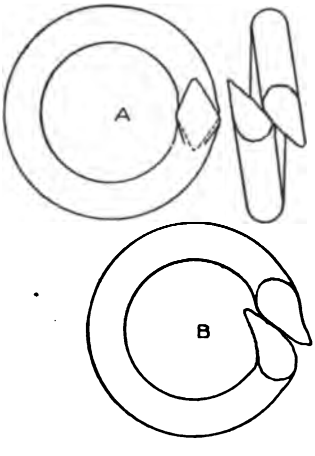
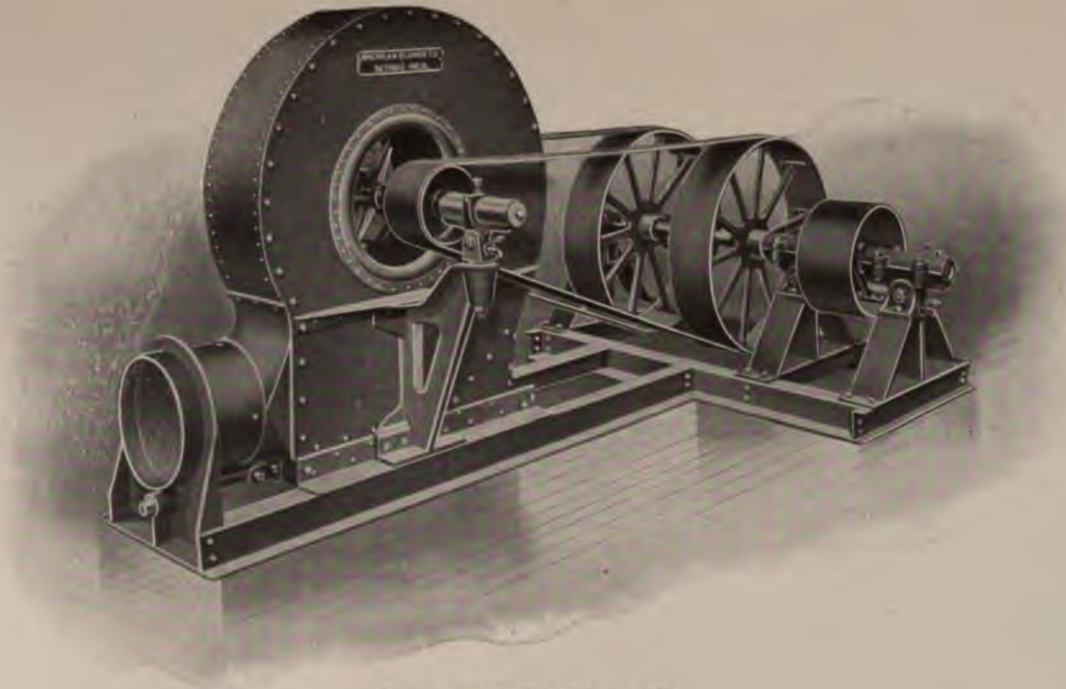


Fig. 20.



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Ring Round Stock. When a ring is made, the exact amount of stock may be cut, the ends upset and scarfed as though making a round lap weld, the stock bent into shape as shown in Fig. 20 and welded. The ends should be lapped sideways as shown. In this position a ring may be welded by simply laying it flat on the anvil, while if lapped the other way, B, one end in, the other out, it would be necessary to do the welding over the horn of the anvil. In all welding the piece should be so lapped that the hammering may be done in the quickest and easiest manner.

Allowance for Welding. In work of this character when the stock is cut to a certain length, allowance is sometimes made for loss due to welding. The exact amount is hard to determine, depending on how carefully the iron is heated and the number of heats required to make the weld. The only real loss which occurs in welding is the amount which is burned off and lost in scale. Of course when preparing for the weld, the ends of the pieces are upset and the stock consequently shortened. The piece is still further shortened by overlapping the ends when making the weld, but as all of this material is afterwards hammered back into shape no loss occurs. No rules can be given for the loss in welding, but as a rough guide on small work, a length of stock equal to from ¼ to ¾ the thickness of the bar will probably be about right for waste. Work of this kind should be watched very closely and the stock measured before and after welding in order to determine exactly how much stock is lost.

Chain Links. The first step in making a chain link is to bend the stock into a "U" shape, care being taken to have the legs of the "U" exactly even in length. The scarf used is approximately the pointed shape used for a round lap weld scarf. An easy method of scarfing is as follows: One end of the "U" shaped piece is laid on the anvil as indicated in Fig. 21. This is flattened by striking directly down with the flat face of the hammer, the piece being moved slightly to the left, as shown by the arrow, after each blow, until the end is reached.

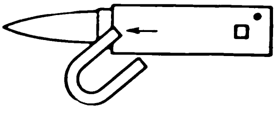

Fig. 21.

This operation leaves a series of little steps at the end of the piece and works it out in a more or less pointed shape as shown in

Fig. 22 at A. The point should be finished by placing it over the horn of the anvil and touching up with a few light blows. After scarfing the other end of the "U" in the same manner the ends are overlapped as indicated at B and welded together. The second link is scarfed, spread open, and the first link inserted. It is then closed up again and welded. The third is joined on this, etc. When made on a commercial scale, light links are not always scarfed but sometimes simply hammered together and welded in one heat. This is not possible in ordinary work.

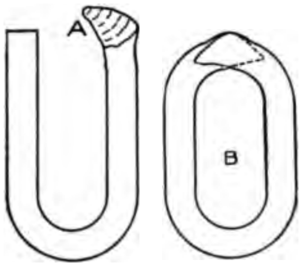

Fig. 22.

Band Ring. A method of making a band ring from iron bent flat ways is illustrated in Fig. 23. Stock is cut to length, the ends upset and scarfed, using a regular flat weld scarf, and the ring bent into shape and welded; the welding being done over the horn of the anvil. The heating must be carefully done or the outside lap will be burned before the inside is nearly hot enough to weld.

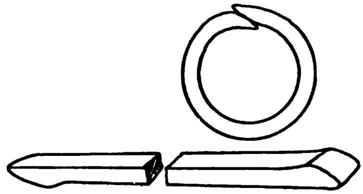
Fig. 23.

Flat or Washer Ring. This is a ring made by bending flat iron edgeways. The ends of the stock are first upset but not scarfed, except for careful work, the ring bent into shape, and the corners trimmed off on radial lines as shown in Fig. 24. The ends are then scarfed with a fuller or pene of a hammer and lapped over ready for welding as shown in Fig. 25.

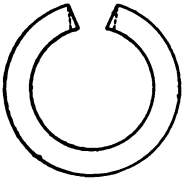
Fig. 24.

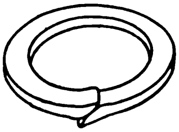
Fig. 25.

Butt Weld. When pieces are simply welded together end to end making a square joint through the weld, it is known as a butt weld. It is best when making a weld of this kind to round the ends slightly as illustrated in Fig. 26. The ends are heated and driven together and this round shape forces out the scale and leaves a clean joint. As the pieces are driven together they are more or less upset at the joint, making a sort of a burr. This upset part should be worked down at a welding heat between swages. A butt weld is not as safe or as strong as a lap weld. Long pieces may be butt welded in the fire. This is done by placing one piece in the fire from each side of the forge. When the welding heat is reached the pieces are placed end to end, one piece "backed up" with a heavy weight, and the weld made by striking with a sledge hammer against the end of the other piece.

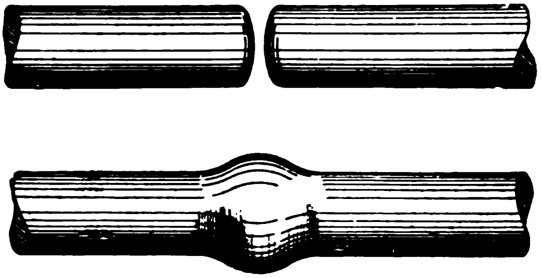

Fig. 26.

Jump Weld. Another form of butt weld shown in Fig. 27 is a jump weld which however is a form which should be avoided as much as possible, as it is very liable to be weak. In making a weld of this kind the piece to be butted on the other should have its end upset in such a manner as to flare out and form sort of a flange, the wider the better. When the weld is made, this flange may be worked down with a fuller or set hammer, thus making a fairly strong weld.

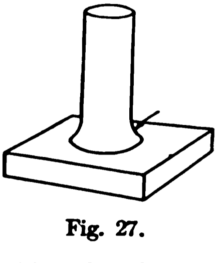

Fig. 27.

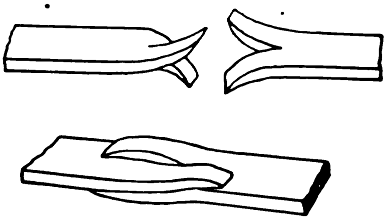

Fig. 28.

Split Weld for Thin Stock. Very thin stock is sometimes difficult to join with the ordinary lap weld for the reason that the pieces lose their heat so rapidly that it is almost impossible to get them together on the anvil before they have cooled below the welding heat. This difficulty is somewhat overcome by shaping the ends as shown in Fig. 28. The ends are tapered to a blunt edge and split down the center for half an inch or so, depending upon the thickness of the stock. Half of each split edge is bent up, the other down, the pieces are driven tightly together and the split parts closed down on each other as shown in Fig. 28. The joint is then heated and welded. This is a weld sometimes used for welding spring steel, or tool steel.

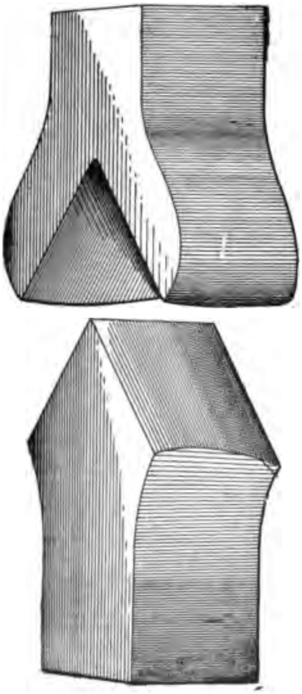

Fig. 29.

Cleft or Split Weld for Heavy Stock. Heavy stock is sometimes welded by using a scarf of the shape shown in Fig. 29. One piece is split and shaped into a "Y" while the other has its end brought to a blunt point. When properly shaped, the pieces are heated to the welding heat and driven together. The ends of the "Y" are then closed down over the other piece and the weld completed. A second heat is sometimes taken to do this. This weld is often used when joining tool steel to iron or machine steel. Sometimes the pieces are placed together before taking the welding heat.

Angle Weld. In all welding it should be remembered that the object of the scarfing is to so shape the pieces to be welded that they will fit together and form a smooth joint when properly hammered. Frequently there are several equally good methods of scarfing for the same sort of a weld, and it should be remembered that the method given here is not necessarily the only way in which that particular weld may be made. Fig. 30 shows one way of scarfing for a right angled weld made of flat iron. Both pieces are scarfed exactly alike, the scarfing being done by the pene end of the hammer. If necessary, the ends of the pieces may be upset before scarfing. Care should

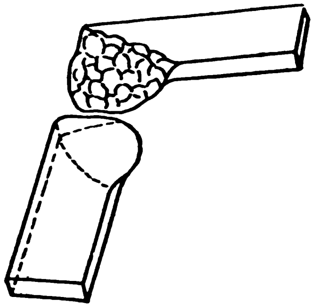

Fig. 30.

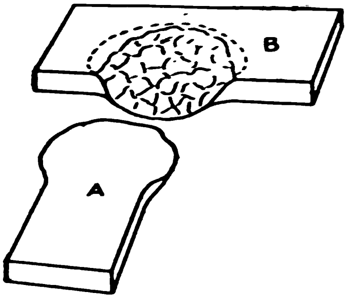

Fig. 31.

be used here as in other welds to see that the pieces touch first in the center of the scarf, otherwise a pocket will be formed which will retain the scale and spoil the weld.

T-Weld. A method of scarfing for a T-weld is illustrated in Fig. 31. The stem A should be placed on the bar B, when welding, in about the position shown by the dotted line.

T-Weld Round Stock. Two methods of scarfing for a T-weld made from round stock are shown in Fig. 32. The scarfs are formed mostly with the pene end of the hammer. The illustration will explain itself. The stock should be well upset in either method.

Welding Tool Steel. The general method of scarfing is the same in all welding but greater care must be used in heating when welding tool steel. The flux used for welding tool steel should be the salammoniac and borax mixture mentioned before. Spring steel or low carbon steel may be satisfactorily welded if care is used. To weld steel successfully the following precautions should be observed. Clean the fire of all cinders and ashes. Put sufficient coal upon the fire so that it will be unnecessary to add more coal while taking the welding heat. Upset both pieces near the end and scarf carefully. When possible, punch a hole and rivet the two pieces together. Heat the steel to a full red heat and sprinkle with borax. Replace in the fire and raise to the welding heat. Clean the scarfed surface and strike lightly at first, followed by heavier blows. The appearance of steel when at a welding heat is a pale straw color.

Always avoid a weld of high carbon steel alone, when possible.

Steel may also be welded to wrought iron. This is done in the manufacturing of edged tools. The body of the tool is of iron, to which a piece of steel is welded to form the cutting edge. This class of work is best done with a fire of anthracite coal, though coke or charcoal may be used. The fire should be burning brightly when the heating is done. Lay the iron and steel on the coal until they are red hot. Then sprinkle the surfaces of both with the flux and let it vitrify. A convenient method of doing this is to have the powdered flux (borax preferred) in a pepper pot. As soon as the heat has changed the metals to a straw color lay them together and strike. A single blow of a drop hammer, or four or five with a light sledge will do the work. Be sure that these pieces are well covered with a flux before attempting to weld.

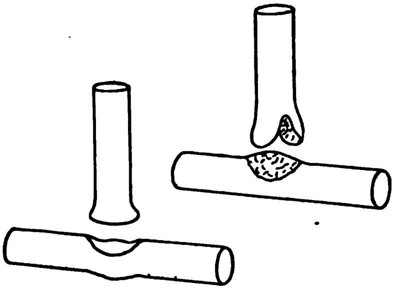

Fig. 32.

CALCULATION OF STOCK FOR BENT SHAPES.

It is always convenient and frequently necessary to know the exact amount of stock required to make a given piece of work. There are four

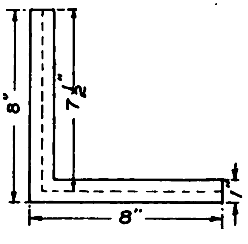

Fig 33.

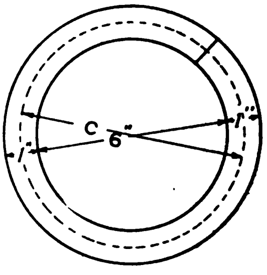

Fig. 34.

general methods used for determining this. The first and most accurate method, if it can be used conveniently, is mathematical calculation. Taking as an example the bent piece illustrated in Fig. 33. If the outside of this be measured, it would seem as though 16 inches of stock were required. If the inside be measured, 14 inches would seem the proper amount. It has been found by experiment that if a piece of straight stock be taken and a line drawn on it through the center, and this piece of stock then be bent and the lengths of the inside, center, and outside lines be measured, the outside line will lengthen considerably as the piece is bent. The inside line will shorten correspondingly, while the center line will remain comparatively unaltered in length. This is universally true, and the proper length of stock required for making any bent shape may always be obtained by measuring the center line of the curve or bend. To return to the first example: In this case, if the center line of the stock be measured, $7\frac{1}{2}$ inches will be the length for each leg, thus making a total of 15 inches of stock required to make that particular bend. This is a universal rule which should always be followed when measuring stock, to take the length of the center line.

Circles. On circles and parts of circles the length of stock may be easily calculated. The circumference, or distance around a circle, is found by multiplying the diameter by $3\frac{1}{7}$ or, more accurately, 3. 1416. As an illustration, the stock necessary to bend up the ring in Fig. 34, would be calculated as follows: The inside diameter of the ring is six inches and the stock is one inch thick. This would make the diameter of the circle made by the center line, shown by C, which may be called the *Calculating Diameter,* seven inches, and the length of stock required would be $7 \times 3\frac{1}{7}$ or 22 inches.

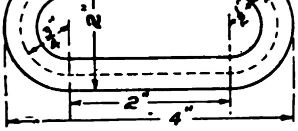

Fig. 35.

Link. A combination of circle and straight lines is illustrated in Fig. 35. This link may be divided into two semicircles at the end, with two straight pieces at the sides. The outside diameter of the ends being two inches, would leave the straight sides each two inches long. The *calculating* diameter for the ends would be $1\frac{1}{2}$ inches. The total length of stock then required for the ends would be $1\frac{1}{2} \times 3\frac{1}{7} = 4\frac{5}{7}$ or approximately $4\frac{1}{1}\frac{1}{6}$ inches. As each of the straight sides will take two inches of stock, the total length required would be $4'' + 4\frac{11}{16}'' = 8\frac{11}{16}$ inches With a slight allowance for welding, the amount cut should be $8\frac{3}{4}''$. Another method of measuring stock is by using a measuring wheel such as is shown in Fig. 36. This is simply a light running wheel mounted on a handle with some sort of a pointer attached. The wheel is sometimes made with a circumference of 24 inches and the rim graduated in inches and eights. To use it, the wheel is placed lightly in contact with the line or object which it is wished to measure, with the zero mark on the wheel corresponding to the point from which the measurement is started. The wheel is then pushed along the surface following the line to be measured, with just enough pressure to cause it to revolve. By counting the revolutions and parts of a revolution made by the wheel, the required distance may be easily measured.

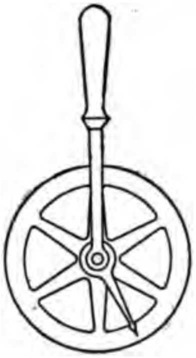

Fig. 36.

Scrolls and Irregular Shapes may be measured by either of two methods. The commoner way is to lay the scroll or shape off full size and measure the length by laying on this full sized drawing a string or thin piece of wire, causing the string or wire to follow the center line of the bent stock. The wire or string is then straightened and the length measured. This is about the easiest and best way of measuring work of this character. Another method which is more practical in the drafting room, consists of using a pair of dividers. The points of the dividers are set fairly close together and the center line is then stepped off and the number of steps counted. The same number of spaces are then laid off along a straight line and the length measured.

FORGING OPERATIONS.

Shaping. After the metal has been heated it is shaped with the hammer. This shaping may consist of drawing, upsetting or bending. In *drawing* a bar of iron it is made longer and of a smaller diameter. *Upsetting* consists of shortening the bar with a corresponding increase of diameter. This work is usually done with a helper using a sledge hammer; the smith using a light hand hammer.

They strike alternate blows. The helper must watch the point upon which the smith strikes and strike in the same place. Where two helpers are employed the smith strikes after each man. A blow on the anvil by the smith is a signal to stop striking.

Finishing. As the hammer usually marks the metal, it is customary to leave the metal a little full and finish by the use of flatters and swages. This applies to work that has been shaped under the sledge. Light work can be dressed smoothly, and the hammer can be made to obliterate its own marks.

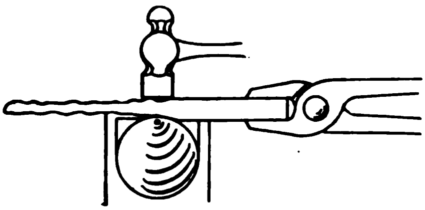

Fig. 37.

Drawing Out. In drawing out as well as in all other forging operations where heavy work is to be done, it is always best to heat the work to as high a temperature as the metal will stand without injury. Work can sometimes be drawn out much faster by working over the horn of the anvil than on the face, the reason being this: When a piece of work is hammered on the anvil face it flattens out and spreads nearly as much in width as it does in length, working it out longer and wider. As the piece is not wanted wider but merely longer, all the work spent in increasing the width of the stock is wasted. If the hammering is done over the horn of the anvil as illustrated in Fig. 37, the rounded horn acts as a blunt wedge, forcing the metal lengthwise and thus utilizes almost the entire energy of a blow in stretching the metal in the desired direction. Fullers are also used to serve the same purpose and when working under the steam hammer a round bar sometimes takes the place of the fuller or horn of the anvil.

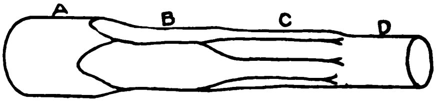

Fig. 38.

Drawing Out and Pointing Round Stock. When drawing out or pointing round stock, it should always first be forged down square to the required size and then in as few blows as possible, rounded up. Fig. 38 illustrates, in a general way, the different steps in drawing down a round bar from a large to a smaller size, the first step being to hammer it down square as at B. This square shape is then made octagonal as at C and the octagon is finally rounded up as at D. If an attempt be made to hammer the bar by pounding it round and round without the preliminary squaring, the bar is very liable to split through the center, the action being a good deal as illustrated in Fig. 39, the effect of the blow coming as shown by the arrows A. The metal is squeezed together in this direction and forced apart in the direction at right angles as indicated by the arrows B. Then if the piece be slightly rolled for another blow, the sides will roll by each other, and cracks and splits will sooner or later develop, leaving the bar, if it should be sawed through the center, in a good deal the shape shown in Fig. 40. Particular care should be taken in making conical points as it is almost impossible to work stock down to a round point unless the point be first forged down to a square or pyramidal shape.

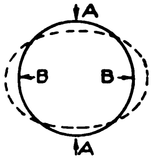

Fig. 39.

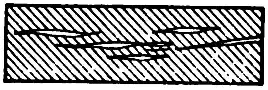

Fig. 40.

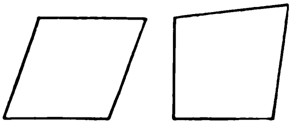

Fig. 41.

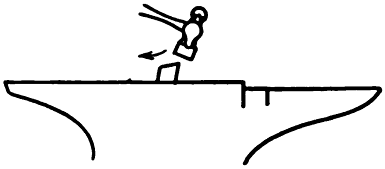

Fig. 42.

Truing Up Work. In drawing out it often happens that the bar becomes worked into an irregular or diamond shape, similar to the section shown in Fig. 41. To remedy this, and square up the bad corners, the bar should be laid across the anvil and worked much as shown in Fig. 42, the blows coming in the direction indicated by the arrow. Just as the hammer strikes the work it should be given a sort of sliding motion. No attempt should be made to square up a corner by striking squarely down upon the work. The hammering should all be done in such a way as to force the metal back into the bar and away from the high corner.

Upsetting. When a piece is worked in such a way that its length is shortened and either or both its thickness and width increased, the piece is said to be upset and the operation is known as upsetting. There are several methods of upsetting, the one used depending largely upon the shape of the work. In short pieces the work is generally stood on end on the anvil, the hammering being done directly down upon the upper end. The work should always be kept straight, and as soon as a bend or kink is started, it should be straightened out. When a long piece is to be upset it is generally swung back and forth horizontally and the upsetting done by ramming the end against the anvil. The effect of the blow has a decided influence upon the shape of the upset piece, as shown by the sketches of the two rivets in Fig. 43. Light blows affect the metal for a short distance only, as shown by the swelled out end, while the effect of heavier blows is felt more uniformly throughout the entire length.

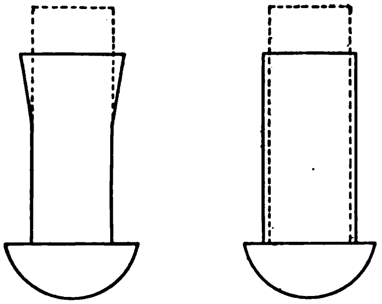

Fig. 43.

When rivets are to be driven to fill holes tightly, the blows should be heavy, thus upsetting the rivet tightly into the holes. If a rivet is wanted to hold two pieces together in such a way that they may move, as for instance the rivet in a pair of tongs, the head should be formed with light blows, thus working only the end of the rivet. The part of the work which is heated to the highest temperature is the part which will be most upset, and when upsetting is wished at one point only, that point should be heated to the highest temperature, leaving the other parts of the bar as cold as possible. Upsetting long pieces is sometimes done by raising the piece and allowing it to drop on a heavy cast-iron plate set in the floor. These plates are known as upsetting plates.

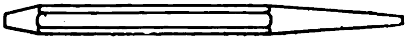

Fig. 44.

Punching. Two kinds of punches are commonly used for making holes in hot metal; the straight hand punch used with a hand hammer and the one used for heavier stock, provided with a handle and used with a sledge hammer. Punches should of course be made of tool steel. For punching small holes in thin iron a hand punch is ordinarily used. This is a bar of round or octagonal steel, eight or ten inches in length, with the end forged down tapering to the same shape, but slightly smaller than the hole to be punched. Such a punch for round holes is shown in Fig. 44. The end of the punch should be perfectly square across, not at all rounding. For heavier and faster work with a helper, a punch similar to Fig. 45 is used, the striking being done with a sledge hammer.

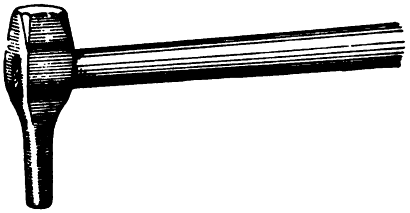
Fig. 45.

Fig. 46 illustrates the successive steps in punching a clean hole through a piece of hot iron. The work is first laid flat on the anvil and the punch driven about half way through as shown at A. This compresses the metal directly underneath the end of the punch and raises a slight bulge on the opposite side of the bar. The piece is then turned over and the punch driven into the bar from this side (the hole being located by the bulge) while the bar is lying flat on the anvil. The punch should be driven about half of the way through, leaving the work as at C. The bar is then moved over the small round hole in the end of the anvil, or is placed on some object having a hole slightly larger than the hole to be punched, and the punch

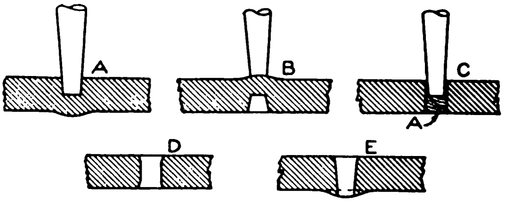

Fig. 46.

driven clear through, driving out the small piece A and leaving the hole as shown at D. It would seem easier to drive the punch completely through the work from one side. If this were done, however, the hole would be left as shown at E, one side would be rounded in, and the other side would be bulged out, while the hole would have a decided taper, being larger at the end from which the punching was done. If the piece be thick, after the hole is started, a little powdered coal is put in and the punching continued. The coal prevents the punch from sticking to some extent.

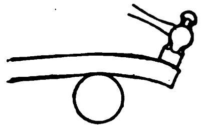

Fig. 47.

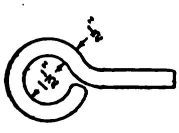

Fig. 48.

Ring and Eye Bending. In making a ring or eye the first step is of course, to calculate the amount of stock required. In making ordinary rings four or five inches in diameter, the stock should be heated for about half its length. In starting the bend, the extreme end of the piece is first bent by placing the bar across the horn of the anvil and bending it down as illustrated in Fig. 47. The bar is then pushed ahead and bent down as it is fed forward. The blows should not come directly on top of the horn but fall outside of the point of support as illustrated. This bends the iron and does not hammer it out of shape. One-half of the circle is bent in this way, the stock turned end for end, the other end heated, and the second half bent in the same way as the first, the bending being started from the end as before.

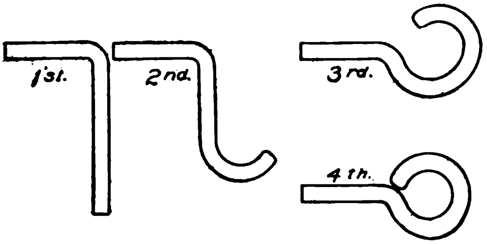

Fig. 49.

Eye bending is done in a somewhat different manner. Suppose it be required to bend up an eye as shown in Fig. 48. To calculate the amount of stock required: The diameter in this case to be used is two inches, and the amount of stock required $2'' \times 3\frac{1}{7}'' = 6\frac{2}{7}''$, or practically $6\frac{3}{8}''$. This distance is laid off by making a chalk mark on the anvil $6\frac{3}{8}''$ from the end. The iron is heated and placed against the anvil with one end on the chalk mark and the other end extending over the end of the anvil. The hand hammer is then held on the bar with one edge at the edge of the anvil, thus measuring off the required distance on the bar. Still holding the hammer on the bar the piece is laid across the anvil, with the edge of the hammer even with the edge of the anvil and the $6\frac{3}{8}$ inches extending over the edge or corner. This piece is then bent down into a right angle as shown in the first illustration of Fig. 49. The eye is bent in much the same manner as the ring, except that all the bending is done from one end, the successive steps being shown in the illustration. Small eyes are closed up in the manner shown in Fig. 50.

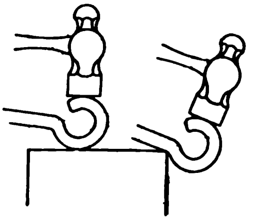
Fig. 50.

Bend with Square Forged Corner. Brackets and other forgings are frequently made with the outside corner square and sharp, as shown at C, Fig. 51. This may be done in either of two ways; by the first method the corner is bent from the size of stock required for the sides, being first bent to the shape of A. This corner is then

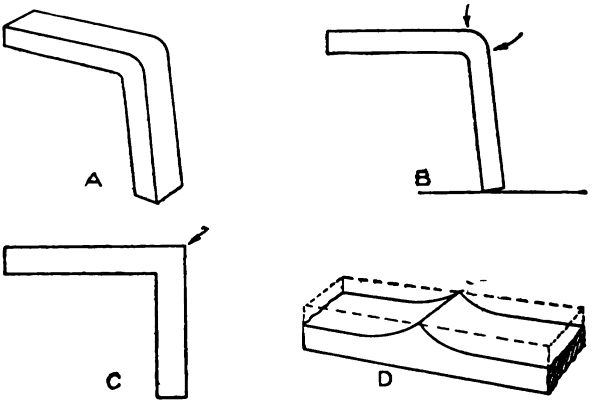

Fig. 51.

squared by upsetting the metal at the bend, the blows coming as shown by the arrows at B. The work should rest on the anvil face, and not over one corner, while being hammered.

The second method is to use thicker stock and draw out the ends leaving a hump, shown at D, where the outside corner of the bend is to come. The dotted lines show the original shape of the bar; the solid lines the shape before bending. Sometimes stock is taken of the size used in the first method and upset to form the ridge, in place of drawing out the heavier stock.

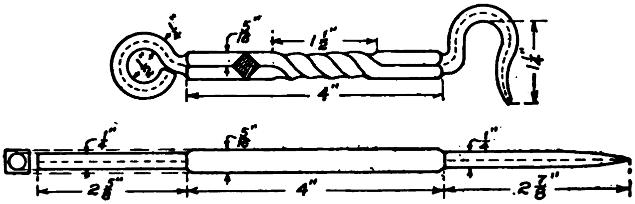

Fig. 52.

The first method is the one more commonly used on medium sized work.

SIMPLE FORGING.

Twisted Gate Hook. It should be understood that the description given here will serve not only as a description of the particular piece in question but also as a general description of a variety of similarly shaped forgings. The methods used may be employed on other forgings of the same general shape.

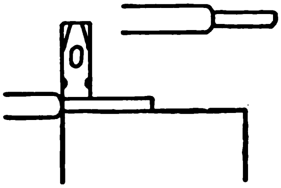

Fig. 53.

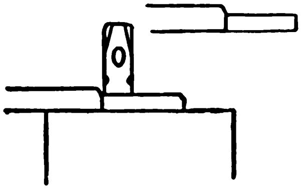

Fig. 54.

Fig. 52 shows a twisted gate hook. To start with, it is necessary to determine exactly what lengths the different parts of the hook will have after they are forged to dimensions, and before they are bent to shape. Before bending, the work is first drawn down to size as is indicated. The bar is left square in the center for the central part, and each end is drawn to one-quarter inch round to form the hook and eye ends. The length of stock after being drawn out to ¼″ round required to make the eye, is 2⅜ inches. Allowing about one-quarter of an inch for the straight part before the eye is reached would make the total amount of stock required for the eye 2⅝ inches. To obtain the amount of stock for the hook it is necessary to lay off the hook full size. If the drawing be full sized the measuring may be done directly on the drawing, but if not, a rough sketch having the proper dimensions should be laid off and the measuring done on that, the measuring of course being done along the dotted center line. This measuring is done by simply laying a string on the dotted line, then straightening out the string and measuring its length. In this way it will be found that 2⅞ inches is required by the hook. The first step is then to forge the work into the shape shown in Fig. 52.

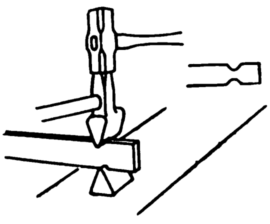

Fig. 55.

Forming Shoulders. The shoulder where the round stock joins the square should be forged in the manner indicated in Fig. 53. The bar is laid across the anvil with the point where the shoulder is wished, lying directly on the corner of the anvil. The set hammer is then placed on top of the work in such a way that the edge of the set hammer comes directly in line with the edge of the anvil. The set hammer is then driven into the work with a sledge hammer. The bar should be turned continually or an uneven shoulder will be the result. If a shoulder is wanted on one side only, as illustrated in Fig. 54, it should be worked in as indicated there. That is, one side of the iron should lie flat on the anvil face while the set hammer works down the metal next to the shoulder.

After the two ends of the hook are drawn out, the eye and the hook are bent up into shape. The twist in the center of the hook may be made by using either two pairs of tongs or twisting in a vise. By the latter method a mark is first made on the vise in such a way that when the end of the hook is placed even with the mark, the edge of the vise will come at the end of the point where the twist is wanted.

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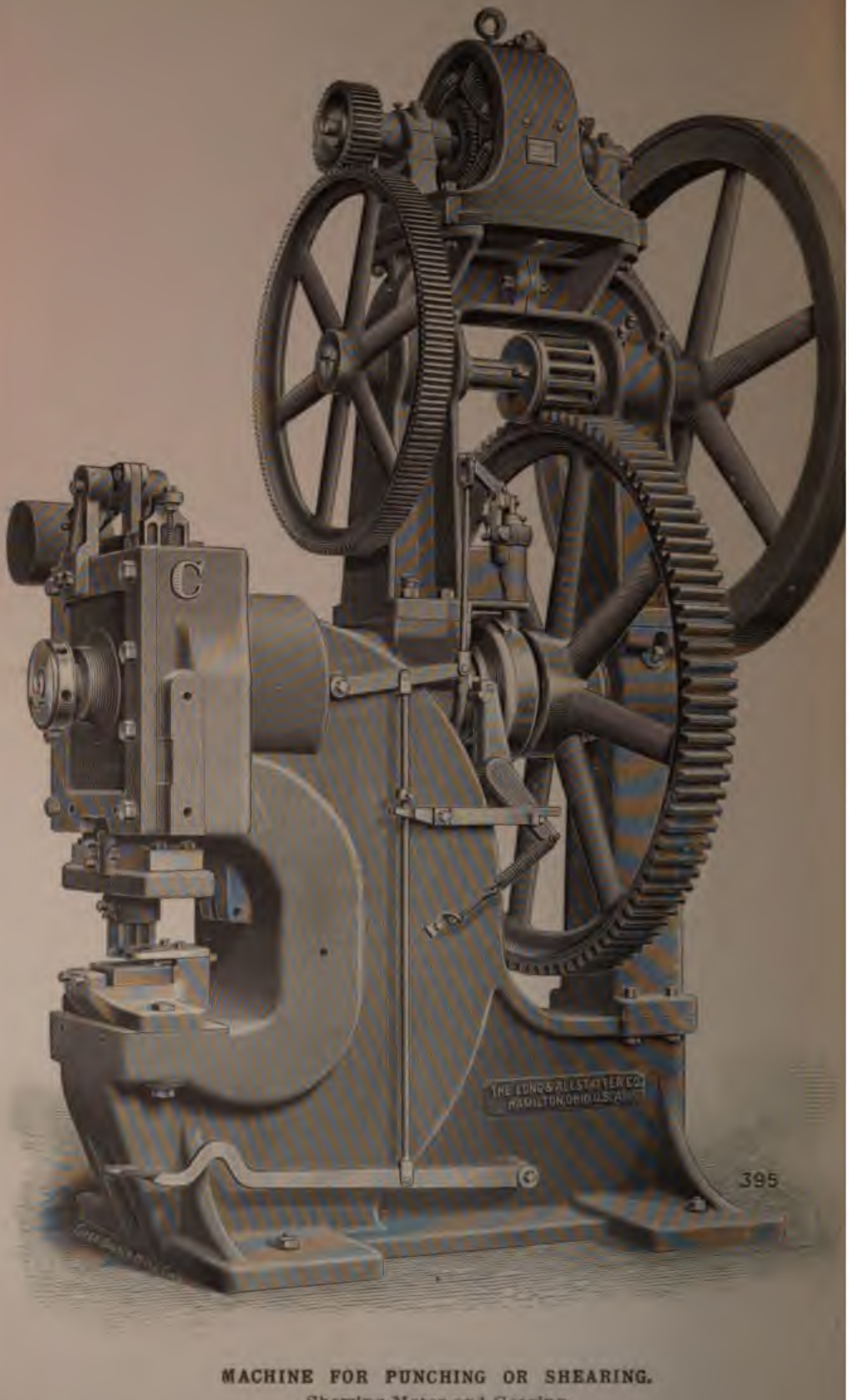
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MACHINE FOR PUNCHING OR SHEARING.
Showing Motor and Gearing.
The Long and Allstatter Co.

The hook should be heated and placed in the vise, the other end being grasped by a pair of tongs in such a way that the distance between the tongs and the vise is just equal in length to the twist. The twist is made by simply revolving the tongs around. In making a twist of this kind, no allowance need be made in length, as it practically has no effect on the length of the stock.

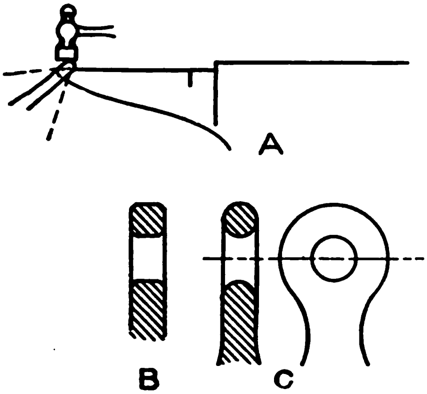


Fig. 56.

Eye Bolts are made by two general methods, being either solid or welded. The solid eye bolt is much the stronger. A solid eye bolt, or forged eye, as it is sometimes called, may be started in the general manner illustrated in Fig. 55. A nick is made on either side of a flat bar by using top and bottom fullers as illustrated. The end is then rounded up as shown in Fig. 56. Particular attention should be given to seeing that the eye is forged as nearly to a perfect circle as possible before any punching is done. The stock around the eye is rounded up over the horn of the anvil, by swinging it back and forth as it is hammered. The hole when first punched is like B, but when finished should be like C. The other end of the bar is then drawn down to form the round shank. If a very long shank is wanted a short stub shank may be formed and a round bar of the proper size welded on.

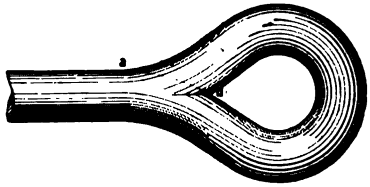


Fig. 57.

Welded eye bolts may be made in two different ways. The easier method produces an eye shaped as in Fig. 57. To make such a bolt, first scarf the end so that it will fit over the bend of the rod along the dotted line *a b*. Bend the eye over the horn of the anvil. Finally bring to a welding heat and weld in accordance with instructions already given.

An eye of better appearance, as shown in Fig. 58, is made as follows: Upset the body of the metal as a seat for the scarf at the end,

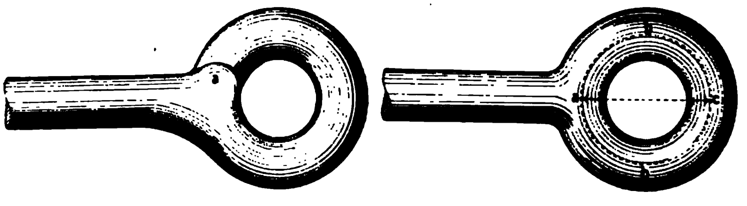


Fig. 58.

shown at *a*, Fig. 58. Scarf the end of the bar and bend over the horn of the anvil into a true circle to fit the seat at *a*, and then weld as before.

The length of metal required for an eye or ring is nearly equal to the length of the circumference of a circle whose diameter is equal to the mean diameter of the ring. Thus in Fig. 58 the length required for the eye will be approximately the length of the circle *a b c b* whose diameter is *a c*.

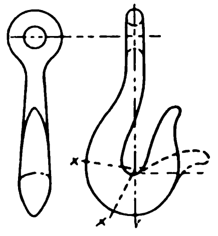


Fig. 59.

Chain Hooks. These are made in a variety of shapes and with solid or welded eyes, the general method of making the eyes being exactly as described before under "Eye Bolts". A common shape is shown in Fig. 59. The stock is forged into shape similar to Fig. 60 before being bent. To determine the length A the drawing is measured in the same way as described in making the gate hook. The weakest point in most hooks is the part lying between the lines marked *x x* in Fig. 59. This part of the hook should be heavier and stronger than the other parts. When a strain is put on the hook, there is always a tendency to straighten out or to assume the shape shown by the dotted lines. When forging the hook into shape, the dimension B, Fig. 60, should be made such that the heaviest part of the hook comes in this weakest point. After the hook is entirely forged to size, it should be bent into shape. Hooks

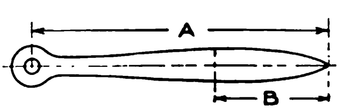


Fig. 60.

are also made from round and square iron. When made for hooking over a link, and so shaped that the throat or opening is just large enough to slip easily over a link edgewise, but too narrow to slip off of this link down to the one which, of course, is turned at right angles, the hook is known as a grab hook.

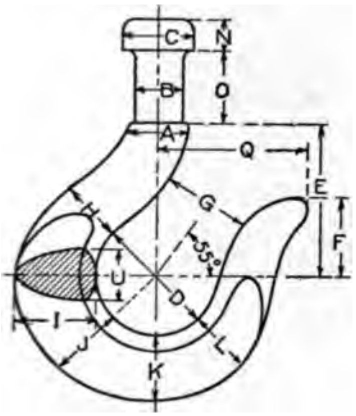


Fig. 61.

Hoisting Hooks. A widely accepted shape for hooks of this character used on cranes is shown on Fig. 61. The shape and formulae for the dimensions are given by Mr. Henry R. Town in his "Treatise on Cranes". T = Working load in tons of 2,000 lbs. A = Diameter of round stock, in inches, used to form the hook. The size of stock required for a hook to carry any particular load is given below. The load for which the hook is designed is given in the upper line, the lower line gives the size of the stock to be used in making the hook.

T =	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{2}$	1	$1\frac{1}{2}$	2	3	4	5	6	8	10
A =	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$1\frac{1}{16}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{7}{8}$	$3\frac{1}{4}$

The other dimensions of the hook are found by the following formulae, all of the dimensions being given in inches.

$D = .5\ T + 1.25$

$E = .64\ T + 1.6$

$F = .33\ T + .85$

$G = .75\ D$

$O = .363T + .66$

$Q = .64\ T + 1.6$

$H = 1.08\ A$

$I = 1.33\ A$

$J = 1.2\ A$

$K = 1.13\ A$

$L = 1.05\ A$

$M = .5\ A$

$N = .85\ B - .16$

$U = .866A$

To illustrate the use of the table, suppose it be required to make a hook to raise a load of 500 lbs. or one-quarter of a ton. In the line marked "T" is found the load $\frac{1}{4}$. Directly below are figures

$\frac{11}{16}$ showing the size of stock to be used. The dimensions of the hook will be found as follows:

$$D = .5 \times \tfrac{1}{4} + 1.25'' = 1\tfrac{3}{8}''.$$
$$E = .64 \times \tfrac{1}{4} + 1.6'' = 1\tfrac{3}{4}''\text{ about.} \qquad \text{Etc.}$$

……

$$I = 1.33\ A = 1.33 \times \tfrac{11}{16} = .915 \text{ or about } \tfrac{29}{32}''.$$

When reducing the decimals the dimensions which have to do only with the bending of the hook, *i.e.*, the opening, length, the length of point, etc., may be taken to the nearest 16th, but the dimensions through the body of the hook or stock should be reduced to the nearest 32nd on small hooks. The completed dimensions of the hook in question, 500 lbs. capacity, would be as follows:

$D = 1\frac{3}{8}''$
$E = 1\frac{3}{4}''$
$F = \frac{15}{16}''$
$G = 1''$
$O = \frac{3}{4}''$
$Q = 1\frac{3}{4}''$
$H = \frac{3}{4}''$
$I = \frac{29}{32}''$
$J = \frac{13}{16}''$
$K = \frac{25}{32}''$
$L = \frac{23}{32}''$
$M = \frac{11}{32}''$
$U = \frac{9}{16}''$

Bolts. Bolts are made by two methods, the head being made by either upsetting or welding. The first method is more common on small bolts and machine made bolts. The welded head is more commonly used for heavy, hand forged bolts. The upset head is the stronger provided both are equally well made. The size of the bolt is always given as the diameter and length of shank or stem. Thus a bolt known as ½″ × 6″, or ½″ bolt 6″ long, would mean a bolt having a shank ½″ in diameter and 6″ long from the under side of the head to the end of the stem, having the dimensions of the bolt shown in Fig. 62. The dimensions of the bolt heads are always the same for the same sized bolt, and are determined from the diameter of the shank. The diameter of the head, shown at D, Fig. 62, is the distance across the head from flat side to flat side, and is known as the diameter *across the flats.*

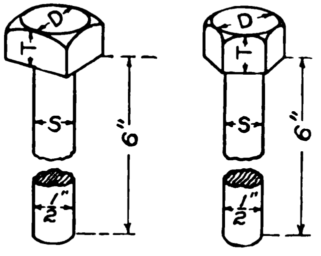


Fig. 62.

The thickness of the head is taken, as shown at T. If S equals the diameter of the shank of the bolt, the dimensions of the head would be as follows:

$$D = 1\tfrac{1}{2} \times S + \tfrac{1}{8}''$$
$$T = S$$

For a two-inch bolt the dimensions would be as follows:

Diameter of head $1\tfrac{1}{2} \times 2'' + \tfrac{1}{8}'' = 3\tfrac{1}{8}''$

The thickness of head would be equal to diameter of the shank, or 2". These dimensions are for rough or unfinished heads. Each dimension of a finished head is $\tfrac{1}{16}$ of an inch less than the same dimension of a rough head. Bolts generally have the top corners of the head rounded or chamfered off. This may be done with a hand hammer; or a cupping tool, which is simply a set hammer with the bottom face hollowed out into a cup shape, may be used.

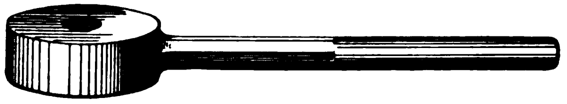


Fig. 63.

Upset Head Bolts. The general method of making bolts of this kind, when a single bolt is wanted, is described below. The method of upsetting is shown in Fig. 64.

Where large quantities of bolts are to be made, the bars are heated in a furnace and headed by special machinery. Where the work is done by hand the tools are of the simplest character. The header consists of a disc in which a hole has been drilled to correspond to the diameter of the bolt. A handle 12 or 15 inches in length is welded to the disc. Such a tool is shown in Fig. 63. The hole should be about $\tfrac{1}{32}$ inch larger than the nominal size of iron. To make a bolt with this tool: First cut off the iron to the required length; then heat the end to be headed, to a dull straw color; strike the end with a hammer or against the anvil and upset it so that the portion intended for the formation of the head will not pass through the header. Then place the hole of the header over the square hole in the tail of the

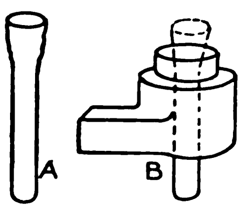


Fig. 64.

anvil and drop the cold end of the bolt through it. Strike the projecting portion of the bar and upset it until the requisite thickness of head is obtained. This will probably leave a head of curved but irregular outline. Remove from the header and square the head thus upset, on the face of the anvil. This will probably thicken the head. Again drop the cold end through the header and strike the head until it is reduced to proper thickness. After which, again square the edges on the face of the anvil. In doing this work, the smith will hold the header in his left hand. The work will be facilitated if a helper assists with a sledge hammer.

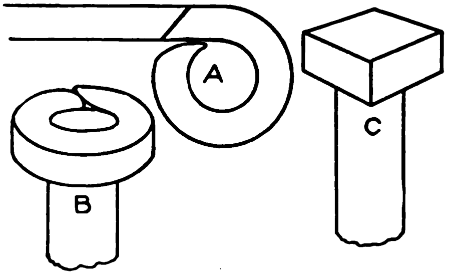


Fig. 65.

There are a number of simple tools in use for clamping the bar while it is being headed so as to avoid the preliminary upsetting.

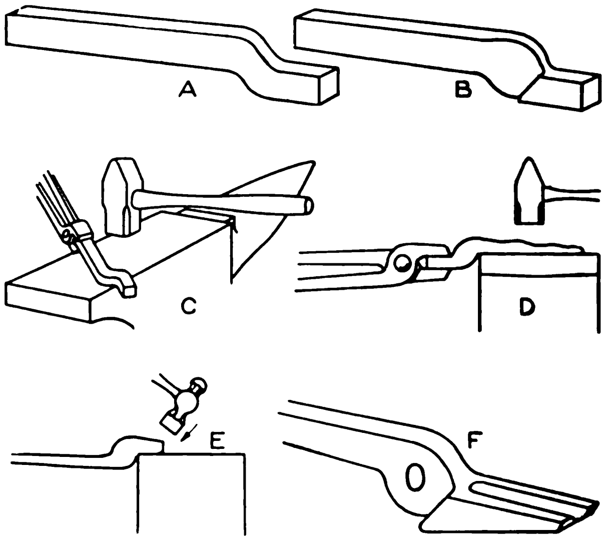


Fig. 66.

Welded Head Bolts are made by welding a ring of square iron around the end of the shank to form the head. The ring is generally bent up on the end of a bar as shown at A, Fig. 65, but not welded. This ring is cut off and placed on the end of the shank as shown at B. The joint in the ring should be left slightly open to allow for the expansion in welding. The ring is fastened to the end of the shank by striking it on one side and squeezing it against the shank. The bolt is put into the fire, heated to the welding heat, and the head welded up into the required shape. The ring should not be welded round at first, as it is difficult in this way to make a sound joint, there being a much better chance of doing sound work by welding the head directly square or hexagonal as required. No attention need be paid to the joint in the ring as this will take care of itself. Considerable care must be used in taking the welding heat, as all the heat which reaches the joint must pass through the ring and there is a good chance of burning the ring before the shank reaches the welding heat if the heating is not done slowly and carefully.

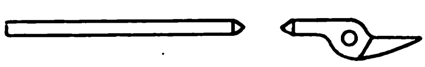


Fig. 67.

Tongs. Common flat jawed tongs, such as are used for holding light work up to about three-quarters of an inch thick, may be made as follows: Stock should be about three-quarters of an inch square. The first step is to make a bend near the end similar to A in Fig. 66. The bent stock is then laid across the anvil in the position shown at C and the eye formed by striking down upon it with a sledge hammer. A set hammer may be used for this work by placing the work flat side down on the top of the anvil and working down the stock for the eye, next to the shoulder, with the set hammer. To make the handle, enough stock may be taken and drawn out as shown at D and a complete handle forged in this way, or a small amount of stock may be taken and a short stub forged out. Enough round stock is then welded on to make the proper length

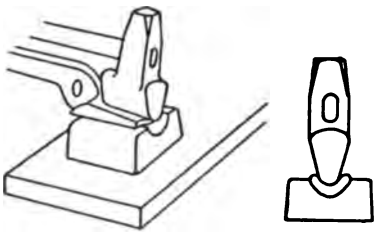


Fig. 68.

of handle, as shown in Fig. 67. The jaw is tapered down as shown at E. The last step is to punch the hole for the rivet. It is always a good plan to slightly crease the inside face of the jaw with a fuller, as this insures the jaws gripping the work firmly with the edges, and not touching it simply at one point in the center, as they sometimes do if this crease is not made. The tongs are then riveted together, the riveting being done with the round end of the hammer; in this way a head is formed on the rivet without upsetting the shank of the rivet very much where it passes through the hole. After riveting, the tongs will probably be stiff or hard to move. They may be loosened up by heating the eye part red hot and moving the handles forward and backward two or three times. They should then be firmly fitted to the work to be handled.

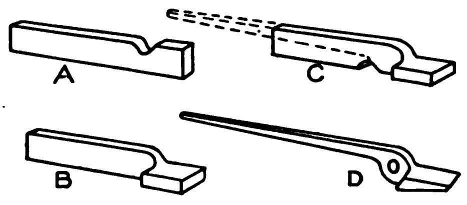


Fig. 69.

Tongs for Round Stock may be made by the general method described above, the only difference being that after the jaws are shaped, and before riveting together, they should be rounded up as illustrated in Fig. 68, using a fuller and swage as shown.

Light Tongs may be made from flat stock in the manner illustrated in Fig. 69. A cut is made in a piece of flat stock, with a fuller, near one end. This end is twisted over at right angles as shown at B. Another cut is made on the opposite side, as at C, and the end drawn out as indicated by the dotted lines. The tongs are then finished in the usual way. Tongs of this character may be used for very light work and are easily made.

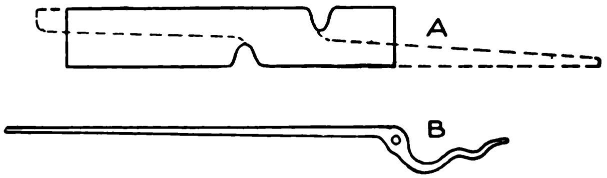


Fig. 70.

Pick-Up Tongs are made in much the same way as described above, the different steps being illustrated in Fig. 70.

Bolt Tongs may be made from round stock, although square may be sometimes used to advantage. The first step is to bend the bar in the shape shown in Fig. 71. This may be done by the fuller at the edge of the anvil, shown at A, or on a swage block as at B. The jaw proper is rounded and finished with a fuller and swage as shown in Fig. 72. The part between the jaw proper and the eye may be worked down into shape by the fuller and set hammer. The finishing may be done as indicated in Fig. 73. The eye and handle are then flattened down and drawn out, the tongs are punched, riveted together, finished, and fitted in the usual manner.

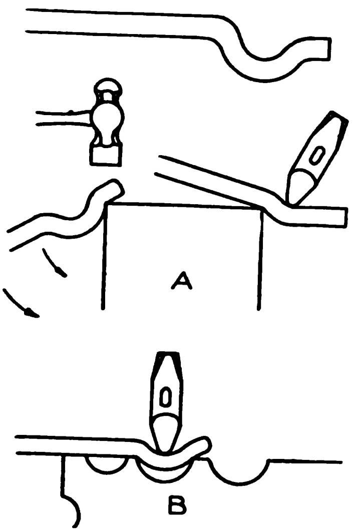


Fig. 71.

Ladles similar to the one shown in Fig. 74, may be made from two pieces welded together, one forming the handle, the other the bowl, or as sometimes is done, the handle may be riveted on. A piece of flat stock is first "laid out" as shown in Fig. 75. This is then cut out with a cold chisel and the handle welded on at the projecting point. The bowl is formed by heating the stock to an even heat and placing it over a round hole in a swage block or other object.

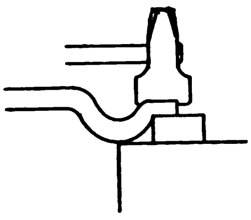


Fig. 72.

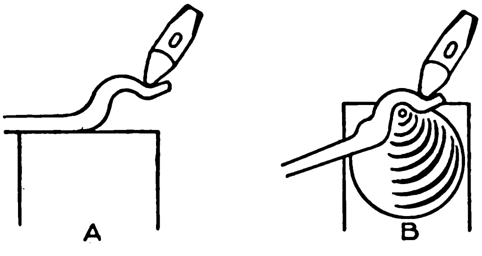


Fig. 73.

This hole should be slightly smaller than the outside diameter of the piece to be worked. To round the bowl it is worked as indicated in Fig. 76, with the pene end of the hammer. The forming should be done as much as possible by working near the edge of the piece rather than in the center. After the bowl has been properly shaped the edges should be ground off smooth and the lips formed as shown in Fig. 77. This is done by placing the part from which the lip is made against one of the small grooves in the side of the swage block and driving in a piece of small round iron, thus hollowing out the lip. The stock draws in somewhat when being rounded up. For the bowl of a ladle 3½″ in diameter, the stock when flat should have an outside diameter of about four inches, and be one-eighth of an inch thick. Machine steel should be used for making the bowl. If ordinary wrought iron is used the metal is almost sure to split.

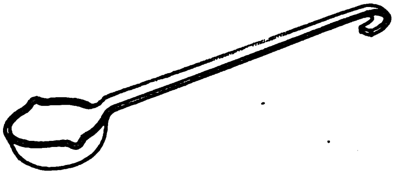


Fig. 74.

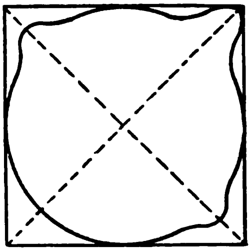


Fig. 75.

CALCULATION OF STOCK FOR FORGED WORK.

The calculations made previously for stock, were for stock which was simply bent into shape, the original section or size of the stock remaining unaltered. There is a large variety of work where the shape of the stock is considerably changed, and where it is essential to know the amount required to make a given forging. In doing this kind of work one rule must be remembered, *i.e.*, that the volume of the stock remains unaltered although its shape may be changed. Take as an example the forging shown in Fig. 78, let us determine the amount of stock required to make the piece.

The forging is made in the general manner shown in Fig. 79. A piece of stock should be taken large enough in section to make the block B, which will mean that it will be one inch wide and half an inch thick. The metal is worked by making the fuller cuts as shown in Fig. 79 and then drawing down the ends to the required size, it being, of course, necessary to know the amount of stock required for each end.

For convenience in calculating, the forging will be divided into three parts, the rounded end A, the central rectangular block B, and the square end C. The stock used being 1″ × ½″ the block B will of course require just two inches of stock. The end C would have a volume of ½″ × ½″ × 3″ = ¾ of a cubic inch. The stock has a volume of, ½″ × 1″ × 1″, = ½ of a cubic inch for each inch of length. The number of inches of stock required for the end C would then be ¾ ÷ ½ or 1½ inches. The end A is a round shaft or cylinder four inches long and ½″ in diameter. To find the volume of a cylinder, multiply the square of the radius (½ the diameter) by 3 1/7 and then multiply this result by the length of the cylinder. This will give the volume of A as ¼ × ¼ × 3 1/7 × 4 = 11/14 and the amount of stock required to make this piece would be 11/14 ÷ ½ = 1 4/7, which may be taken as 1⅝ inches. There is, of course, some slight loss due to scaling in working the

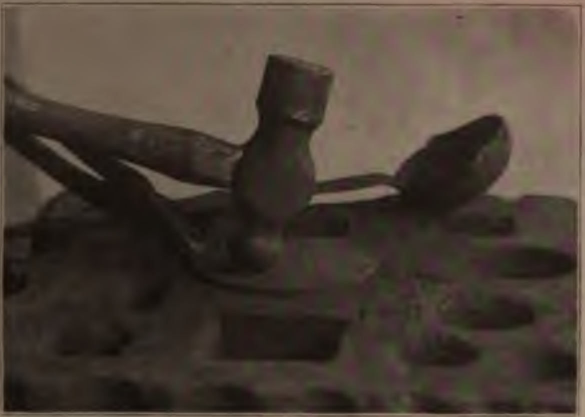


Fig. 76.

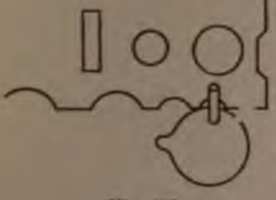


Fig. 77.

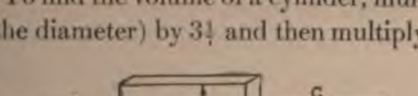


Fig. 78.

iron, which must be allowed for. This is generally done by adding a slight amount to the minimum amount required in each case. The amount of stock required in this case would be about,

Round shaft A	1¾"
Block B	2"
Square shaft C	1⅝"
Total	5⅜"

When the forging is started, cuts, which are afterward opened up with a fuller, may be made as shown by the upper sketch in Fig. 79.

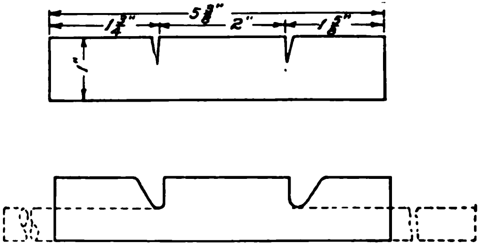


Fig. 79.

In this particular case it is not absolutely necessary that exactly the proper amount of stock be taken, as it would be a very easy matter to take a little too much and trim off the surplus from the ends, after the forging was made.

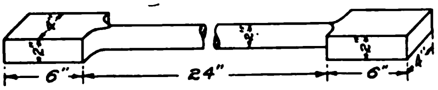


Fig. 80.

With the forging such as shown in Fig. 80, however, it is essential that the exact amount be used. This forging, which is the general shape of a connecting rod, would be started as shown in Fig. 81, and it is quite important that the distance A be correct. The stock used should be 2" × 4". Each end will, of course, require just 6" of stock. The center part is a cylinder 2" in diameter and 24" long, the volume of which would be 1" × 1" × $3\frac{1}{7}$ × 24" = $75\frac{3}{7}$ cubic inches, which may be taken as $75\frac{1}{2}$ cubic inches. For each inch in length the 2" × 4" stock would

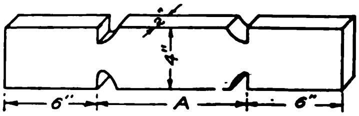


Fig. 81.

have a volume of 4″ × 2″ × 1″ = 8 cubic inches. Therefore it would require $75\frac{1}{2} \div 8 = 9\frac{7}{16}''$ of stock, to form the central piece, consequently the distance between the cuts shown at A in Fig. 81 will be $9\frac{7}{16}''$. To this might be added a slight allowance for loss in scaling. The total amount of stock required would be $6'' + 6'' + 9\frac{7}{16}'' = 21\frac{7}{16}''$. Any forging may generally be separated into simple parts of uniform shape as was done above. In this form the calculation may be easily made.

Weight of Forging. To find the weight of any forging the volume may first be found in cubic inches and this multiplied by .2779, the weight of wrought iron per cubic inch. If the forging be made of steel, the figures .2936 should be used in place of .2779. This gives the weight in pounds. Below is given the weight of wrought iron, cast iron and steel both in pounds per cubic inch and per cubic foot.

Cast Iron	450 per cu. ft.	.2604 per cu. inch.
Wrought Iron	480 " " "	.2779 " " "
Steel	490 " " "	.2936 " " "

Suppose it were required to find the weight of the forging shown in Fig. 78. A has a volume of $\frac{11}{14}$ cubic inch, C $\frac{3}{4}$ cubic inch and B 1 cubic inch, making a total of $2\frac{15}{28}$ cubic inches. If the forging were made of wrought iron it would weigh $2\frac{15}{28} \times .2779 =$ .7 lbs. The forging in Fig. 80 has a total volume of $171\frac{3}{7}$ cubic inches and would weigh, if made of wrought iron, 47.64 lbs.

A much easier way to calculate weights is to use tables such as given on pages 46 and 47. The first table gives the weights *per foot* of flat iron bars. In the second table is given the weights for each foot of length of round and square bars.

When using the table on page 46 to ascertain the weight of any size of flat iron per foot of length, look in the first column at the left for the thickness. Then follow out in a horizontal line to the column giving the width. The number given will be the weight in pounds of one foot of the desired size.

To use the table for calculating weights, the procedure would be as follows:

Taking Fig. 80 as an example, each end is 2″ × 4″ and 6″ long and the two ends would be equal, as far as weight is concerned, to a bar

WEIGHT OF FLAT ROLLED IRON.

Length, 12 inches.

Thickness.	WIDTHS.																				
	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2	2⅛	2¼	2⅜	2½	2⅝	2¾	2⅞	3
⅛	.208	.260	.313	.365	.417	.469	.521	.573	.625	.677	.729	.781	.833	.885	.938	.989	1.04	1.09	1.15	1.20	1.25
¼	.416	.521	.625	.729	.833	.938	1.04	1.15	1.25	1.35	1.46	1.56	1.67	1.77	1.88	1.98	2.08	2.18	2.29	2.39	2.50
⅜	.624	.781	.938	1.09	1.25	1.41	1.56	1.72	1.88	2.03	2.19	2.35	2.50	2.65	2.81	2.97	3.13	3.28	3.44	3.59	3.75
½	.833	1.04	1.25	1.46	1.67	1.88	2.08	2.29	2.50	2.71	2.92	3.13	3.33	3.54	3.75	3.96	4.17	4.37	4.58	4.79	5.00
⅝		1.30	1.56	1.82	2.08	2.35	2.60	2.86	3.13	3.39	3.65	3.91	4.17	4.43	4.69	4.95	5.21	5.47	5.73	5.99	6.25
¾			1.88	2.19	2.50	2.81	3.13	3.44	3.75	4.06	4.38	4.69	5.00	5.31	5.63	5.94	6.25	6.56	6.88	7.19	7.50
⅞				2.55	2.92	3.28	3.65	4.01	4.38	4.74	5.10	5.46	5.83	6.19	6.57	6.92	7.29	7.65	8.02	8.38	8.75
1					3.33	3.75	4.17	4.58	5.00	5.42	5.83	6.25	6.67	7.08	7.50	7.91	8.33	8.75	9.17	9.58	10.00
1⅛						4.22	4.69	5.15	5.63	6.09	6.56	7.03	7.50	7.97	8.44	8.90	9.38	9.84	10.31	10.78	11.25
1¼							5.21	5.73	6.25	6.77	7.29	7.81	8.33	8.85	9.38	9.89	10.42	10.94	11.46	11.98	12.50
1⅜								6.30	6.88	7.45	8.02	8.59	9.17	9.74	10.32	10.88	11.46	12.03	12.60	13.17	13.75
1½									7.50	8.12	8.75	9.37	10.00	10.62	11.25	11.87	12.50	13.12	13.75	14.37	15.00
1⅝										8.80	9.45	10.14	10.83	11.51	12.19	12.86	13.54	14.22	14.90	15.57	16.25
1¾											10.21	10.94	11.67	12.40	13.13	13.85	14.58	15.31	16.04	16.77	17.50
1⅞												11.72	12.50	13.28	14.06	14.84	15.63	16.41	17.19	17.97	18.75
2													13.33	14.16	15.00	15.83	16.67	17.50	18.33	19.16	20.00
2⅛														15.05	15.94	16.81	17.71	18.59	19.48	20.36	21.25
2¼															16.88	17.80	18.75	19.69	20.63	21.56	22.50
2⅜																18.80	19.79	20.78	21.78	22.76	23.75
2½																	20.83	21.87	22.93	23.96	25.00
2⅝																		22.97	24.07	25.16	26.25
2¾																			25.21	26.35	27.50
2⅞																				27.55	28.75
3																					30.00

2″ × 4″ and 1 ft. long. From the table it will be seen that a bar 2″ × 2″ weighs 13.33 lbs. and a bar 2″ × 4″, being twice as thick would weigh twice that, or 26.66 lbs. A bar two inches in diameter weighs 10.47 lbs. per foot and as the central part of the forging is 2 ft. long, it will weigh 20.94 lbs., making the total weight of the forging 47.6 lbs.

Finish. Many forgings are machined or "finished" after leaving the forge shop. The drawings are always made to represent the finished work and therefore give the finished dimensions, and it is necessary when this finishing is to be done, to make allowance for it when making the forging, that all parts which have to be *finished* or "machined" may be left with extra metal to be removed in finishing. The parts required to be finished are generally marked on the drawing. Sometimes the finished surfaces have the word "finished" marked on them. Sometimes the finishing is shown simply by the symbol f, as used in Fig. 82, showing that the shafts and pin only of the crank are to be finished. When all surfaces of a piece are to be finished the words *finish all over* are sometimes marked on the drawing.

WEIGHTS OF ROUND AND SQUARE ROLLED IRON.
Length, 12 Inches.

Thickness or Diameter in Inches.	Weight of Square Bar One Foot Long.	Weight of Round Bar One Foot Long.	Thickness or Diameter in Inches.	Weight of Square Bar One Foot Long.	Weight of Round Bar One Foot Long.	Thickness or Diameter in Inches.	Weight of Square Bar One Foot Long.	Weight of Round Bar One Foot Long.
0			11/16	24.08	18.91	3/8	96.30	75.64
1/16	.013	.010	3/4	25.21	19.80	7/16	98.55	77.40
1/8	.052	.041	13/16	26.37	20.71	1/2	100.8	79.19
3/16	.117	.092	7/8	27.55	21.64	9/16	103.1	81.00
1/4	.208	.164	15/16	28.76	22.59	5/8	105.5	82.83
5/16	.326	.256	3	30.00	23.56	11/16	107.8	84.69
3/8	.469	.368	1/16	31.26	24.55	3/4	110.2	86.56
7/16	.638	.501	1/8	32.55	25.57	13/16	112.6	88.45
1/2	.833	.654	3/16	33.87	26.60	7/8	115.1	90.36
9/16	1.055	.828	1/4	35.21	27.65	15/16	117.5	92.29
5/8	1.302	1.023	5/16	36.58	28.73	6	120.0	94.25
11/16	1.576	1.237	3/8	37.97	29.82	1/8	125.1	98.22
3/4	1.875	1.473	7/16	39.39	30.94	1/4	130.2	102.3
13/16	2.201	1.728	1/2	40.83	32.07	3/8	135.5	106.4
7/8	2.552	2.004	9/16	42.30	33.23	1/2	140.8	110.6
15/16	2.930	2.301	5/8	43.80	34.40	5/8	146.3	114.9
1	3.333	2.618	11/16	45.33	35.60	3/4	151.9	119.3
1/16	3.763	2.955	3/4	46.88	36.82	7/8	157.6	123.7
1/8	4.219	3.313	13/16	48.45	38.05	7	163.3	128.3
3/16	4.701	3.692	7/8	50.05	39.31	1/8	169.2	132.9
1/4	5.208	4.091	15/16	51.68	40.59	1/4	175.2	137.6
5/16	5.742	4.510	4	53.33	41.89	3/8	181.3	142.4
3/8	6.302	4.950	1/16	55.01	43.21	1/2	187.5	147.3
7/16	6.888	5.410	1/8	56.72	44.55	5/8	193.8	152.2
1/2	7.500	5.890	3/16	58.45	45.91	3/4	200.2	157.2
9/16	8.138	6.392	1/4	60.21	47.29	7/8	206.7	162.4
1 5/8	8.802	6.913	5/16	61.99	48.69	8	218.3	167.6
11/16	9.492	7.455	3/8	63.80	50.11	1/4	226.9	178.2
3/4	10.21	8.018	7/16	65.64	51.55	1/2	240.8	189.2
13/16	10.95	8.601	1/2	67.50	53.01	3/4	255.2	200.4
7/8	11.72	9.204	9/16	69.39	54.50	9	270.0	212.1
15/16	12.51	9.828	5/8	71.30	56.00	1/4	285.2	224.0
2	13.33	10.47	11/16	73.24	57.52	1/2	300.8	236.3
1/16	14.18	11.14	3/4	75.21	59.07	3/4	316.9	248.9
1/8	15.05	11.82	13/16	77.20	60.63	10	333.3	261.8
3/16	15.95	12.53	7/8	79.22	62.22	1/4	350.2	275.1
1/4	16.88	13.25	15/16	81.26	63.82	1/2	367.5	288.6
5/16	17.83	14.00	5	83.33	65.45	3/4	385.2	302.5
3/8	18.80	14.77	1/16	85.43	67.10	11	403.3	316.8
7/16	19.80	15.55	1/8	87.55	68.76	1/4	421.9	331.3
1/2	20.83	16.36	3/16	89.70	70.45	1/2	440.8	346.2
9/16	21.89	17.19	1/4	91.88	72.16	3/4	460.2	361.4
5/8	22.97	18.04	5/16	94.08	73.89	12	480.	377.

The allowance for finishing on small forgings is generally about 1/16″ on each surface. Thus, if a block were wanted to finish 4″ × 2″ × 1″ and 1/16″ were allowed for finishing, the dimensions of the forging would be 4⅛″ × 2⅛″ × 1⅛″. On a forging like Fig. 80, about ⅛″ allowance would be made for finishing, if it were called for. Thus the diameter of the central shaft would be 2¼″, the thickness of the ends 2¼″, etc. On larger work ¼″ is sometimes allowed for machining. The amount of finish allowed depends to a large extent on the way the forging is to be finished. When hand finishing is done, that is, filing or scraping, 1/32″ or even 1/64″ is enough; when all of the finishing is done in a lathe or other machine, more material should be left.

When a forging calls for *finish*, in calculating the amount of stock, or weight, the dimensions taken should not be the actual ones shown by the drawing, but these dimensions with the proper allowance made for *finish*.

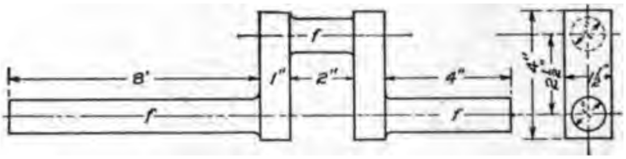


Fig. 82.

Crank Shafts. There are several methods of forging crank shafts. The more commonly used is the commercial method, as described in detail below When forgings were mostly made of wrought iron, the cranks were welded up of severel pieces. One piece was used for each of the shafts, one piece for each cheek or side, and another piece for the crank pin. Cranks are sometimes bent up out of round stock, but this method is only used on small work. The common method now employed where machine steel is used, is to forge the crank from one solid piece of material. The stock is taken large enough to shape the largest part of the crank without any upsetting. If a crank be required similar to Fig. 82, the size of stock to be used should be 1½″ by 4″ in section.

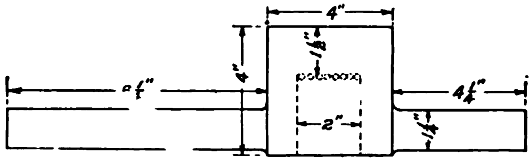


Fig. 83.

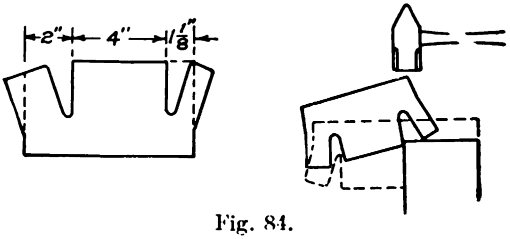
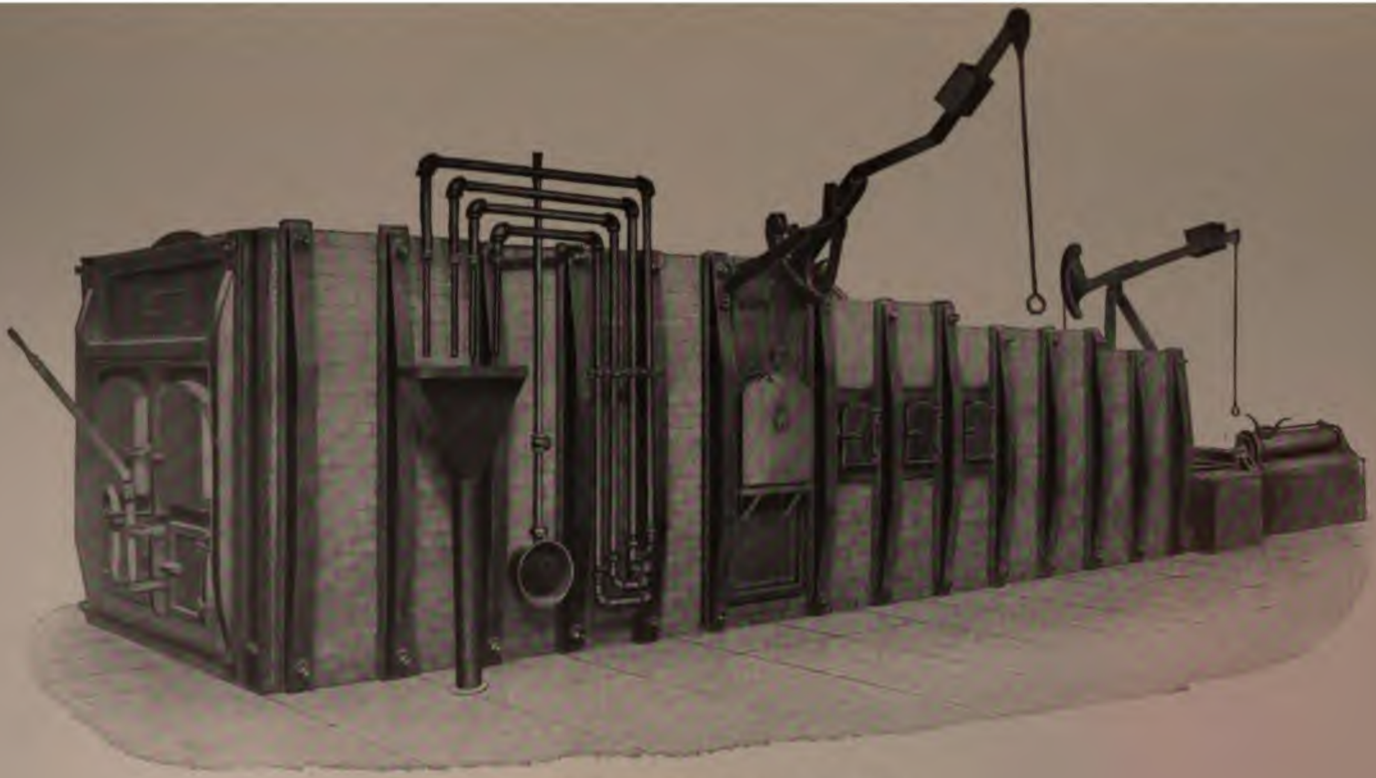


Fig. 84.



AUTOMATIC BILLET-HEATING FURNACE.
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When the forging leaves the shop, it will be left in a shape similar to the shape shown by the solid lines in Fig. 83, the dimensions shown here allowing for the necessary finishing. The crank itself would be left in a solid block, the throat being afterwards cut out as indicated by the dotted lines. A line of holes is first drilled as shown, and the block of metal to be taken out is removed by making two slits with a cold saw and the block then knocked out with a sledge hammer. It is possible to form this throat by chopping out the surplus metal with a hot chisel in the forge shop, but on small cranks in particular, such as here shown, it is generally cheaper in a well equipped shop to use the first method.

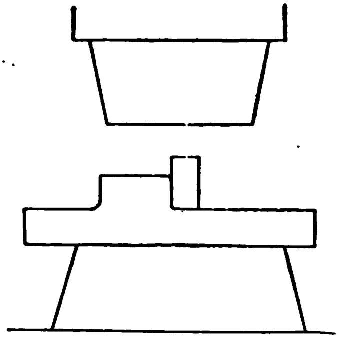

Fig. 85.

The first step is of course to calculate the amount of stock required. The long end would contain 10.13 cubic inches. As each inch of stock contains 6 cubic inches, it would require 1.7″ of stock to form this end provided there was no waste from scale. Waste does take place, however, and must be allowed for, so about 2″ of stock should be taken. The short end contains 5.22 cubic inches and would require .87″ of stock, without allowance for scale. About 1⅛″ should be taken. The total stock then required would be 7⅛″.

The first step is to make the cuts, and spread the ends as shown in Fig. 84. These ends may then be forged down with a sledge hammer as illustrated or may be worked out under the steam hammer, the finishing up against the shoulders being done as illustrated in Fig. 85. The shaft may be rounded down and finished between swages. Care must be taken to see that the cuts are properly spread before drawing out the ends. If the cuts are left without spreading, the metal will act somewhat after the manner shown in Fig. 86. The top part of the bar, as it is

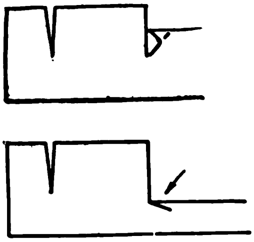

Fig. 86.

worked down, will fold over and leave a crack or *cold shut* as illustrated. When the metal starts to act in this way the fault should be corrected by trimming off the overlapping corner along the dotted line shown in the upper sketch.

Multiple-Throw Cranks. When a crank shaft has more than one crank or crank pin, it is spoken of as a multiple-throw crank. A double-throw crank is a crank shaft with two cranks. A three throw or triple throw, one with three cranks, etc. As a general rule multiple-throw cranks are forged flat, *i.e.*, the cranks are all forged in line with each other. The shafts and pins are then rough turned and the cranks are heated and twisted into shape. The forging for the double-throw crank shown in Fig. 87 would first be made in the general shape shown in Fig. 88. The parts shown by the dotted lines would then be cut out with a drill and saw as described above, and the shafts and pins rough turned, *i.e.*, turned round, but left as large as possible. The forging is then returned to the forge shop where it is heated and the cranks twisted to the desired angle. When twisting, the crank would be gripped just to the right of the point marked A. This may be done with a vise, or wrench if the crank is small, or

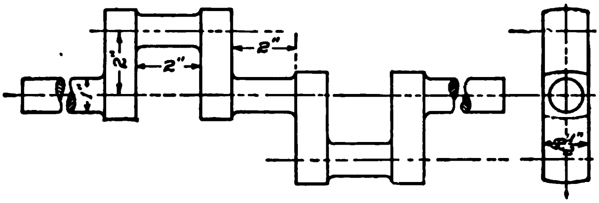

Fig. 87.

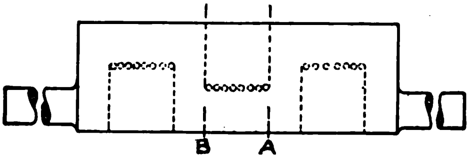

Fig. 88.

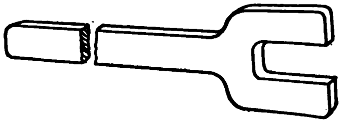

Fig. 89.

it may be held under the steam hammer. The twisting may be done with a wrench similar to Fig. 89 which may be easily made by bending up a U of flat stock and welding on a handle.

A Three-Throw Crank without any intermediate bearings is shown in Fig. 90. The rough forging for this is shown in Fig. 91. The extra metal is removed as indicated by the dotted lines and the twisting done as described before.

Weldless Rings. Rings and eyes forged solid without any welds may be made in the general manner described below. As an example, suppose it be required to make a ring such as illustrated in Fig. 92. A flat bar is first forged rounding on the ends, punched and split as shown, this split is opened out and the ring hammered into shape. It is necessary, of course, to calculate the amount of stock required. This may be done as follows: The first step is to determine the area of the ring, which is done by taking the area of the outside circle, and subtracting from it the area of the inside circle.

Area of outside circle	12.57	sq. in.
" " inside "	7.07	" "
" " ring	5.50	" "

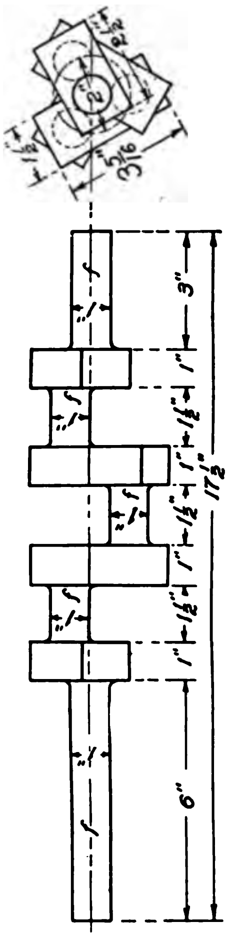

Fig. 90.

The stock used when making small thin rings should be twice

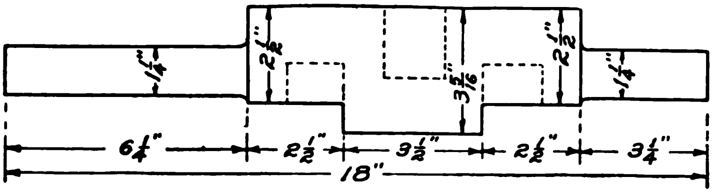

Fig. 91.

the width of the side of the ring to which is added at least one-quarter of an inch. When the bar is split the stock is more or less deformed and when worked back into shape is slightly thinned. Although no stock is lost by the hammering, an allowance must be made for the thinning and stretching and it is necessary to make the stock slightly wider on this account, as noted above. Allowing ½" for hammering, and taking stock 1½" wide, the amount of stock required would be 5.5 ÷ 1.5, equal to 3.66". Allowing a small amount for loss by scale, etc., 3$\frac{11}{16}$" of stock should be taken. In making this calculation, the thickness of the stock is not taken into consideration, as the thickness of the finished ring is the same as the stock. This general method is used on a large variety of work, particularly where rings are to be made of tool steel and should be made without a weld.

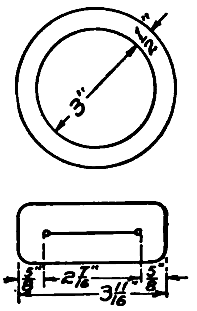

Fig. 92.

Another method of making weldless rings, under the steam hammer, is illustrated in Fig. 93. The proper amount of stock is first forged into a disk, a hole is punched into this disk and a *mandril* inserted. A U-shaped rest is then placed on the anvil of the steam hammer and the mandril laid on this. The ring is turned on the mandril and forged into shape. Larger and larger mandrils are substituted as the hole in the ring increases in size.

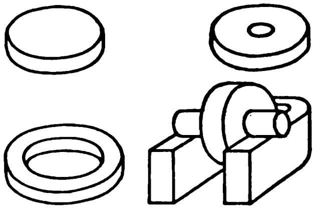

Fig. 93.

Lever with Boss. The following description will serve for many forgings of the same general shape. The forging shown in

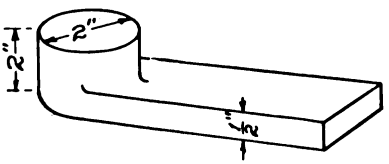

Fig. 94.

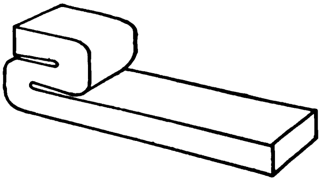

Fig. 95.

Fig. 94 will be taken as an example. There are two general ways of making work of this character. One is to take stock of the proper size for the lever and weld on a chunk for the boss. The other is to take stock large enough to form the boss and draw out either the entire lever, or a short stub, to which the lever is welded. The work may be started for the first method by doubling over the end of the stock as illustrated in Fig. 95. This is welded up and rounded by the same general method as afterwards described for the other boss. The second method of shaping is illustrated in Fig. 96. The stock in this case would be two inches square. The fuller cut is first made as illustrated at A. The end is then drawn out into the shape shown at B. In drawing out the stock, if the metal be allowed to flatten down into shape like C, a "cold-shut" will be formed close to the boss, as the corner at X will overlap and work into the metal, making a crack in the work. The proper way to draw out the stock is shown at D. The square piece left for the boss is rounded up over the cor-

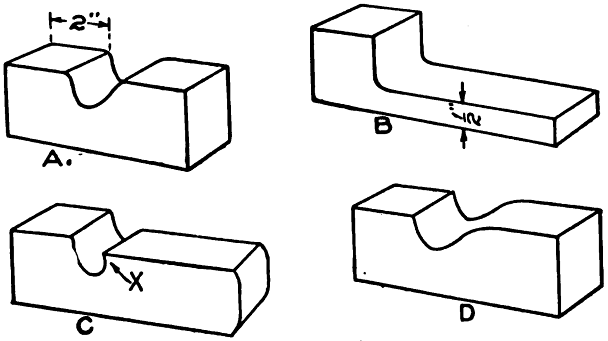

Fig. 96.

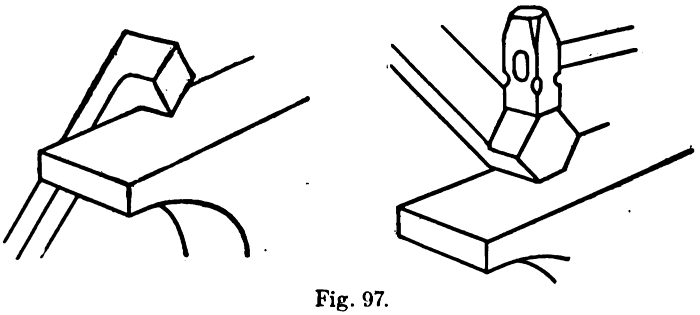

Fig. 97.

ner of the anvil as shown in Fig. 97. Sometimes to make the work easier to get at, the end is bent back out of the way and straightened after the forging is completed. The boss may be smoothed up by using a set hammer or swage in the manner indicated.

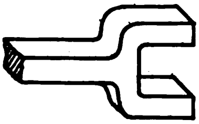

Fig. 98.

Knuckles. One example of a very numerous class of forgings is shown in Fig. 98. This is the shape used for what are known as marine ends of connecting rods, knuckle joints on valve rods, and various other places. A common method employed to make such a forging is shown in Fig. 99. Two fuller cuts are first made as indicated at A and the part for the shaft of the forging drawn out. The thick end is then punched and split, as indicated at B. This split end is opened up and forged out in the manner indicated in Fig. 100, if the work is done on the anvil. Fig. 101 illustrates the method of working out under the steam hammer, the end being first flattened as indicated and then gradually tipped up to the position shown by the dotted lines. When drawn to size, the ends are flattened out straight across and the finishing done around the shank with a fuller as indicated in Fig. 102. The forging is then bent into a U-shaped loop of approximately the shape of the finished knuckle. A bar of iron the same dimension as the inside of the finished knuckle is inserted between the sides of the loop, and the sides closed down flat as shown in Fig. 103. Fig. 104 shows other forgings which may be shaped by this same general method. Trim E, Fig. 99, to the dotted line.

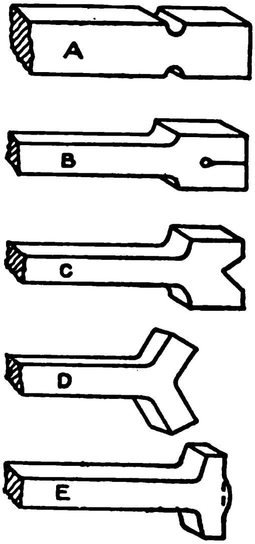

Fig. 99.

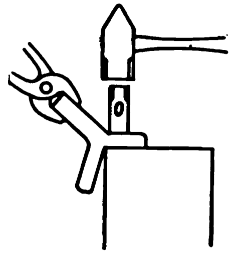

Fig. 100.

Wrenches. A simple tool that is frequently called for is the S wrench. This wrench is usually made with a gap at each end suited for nuts of different sizes. It is shown complete in Fig. 105.

The jaws at the end should be parallel with each other. A line drawn from one jaw to the other should make an angle of 30 degrees with the center line of each. There are two ways in which such a wrench can be forged. One is to forge the jaws separately and then weld to the handle. In the other the jaws are cut from a solid piece of metal and the iron between is then drawn down to the proper size for the handle. The latter is preferable, since it avoids all welds. To make the wrench by the second process, select a piece of steel large enough to form the head. Fuller it down back of the head as shown in A, Fig. 106, at *a a*. Round the end and punch the hole *b*. Next treat the other end in the same way and draw out the intermediate metal giving the form shown at B. Now cut out the holes *b b* securing

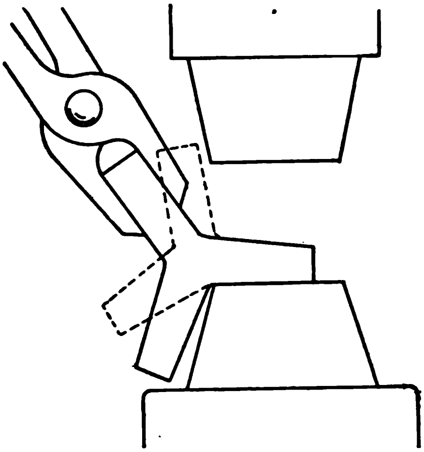

Fig. 101.

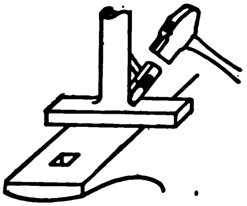

Fig. 102

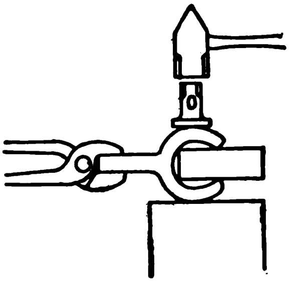

Fig. 103.

the form shown at C. It now remains to bend the heads to the proper angle and give the desired curve to the shank. In forging such a wrench the outer edges should be slightly rounded so that they will not cut the hand. The inside of the jaws should be perfectly square with sharp edges. This finish can be best obtained by filing.

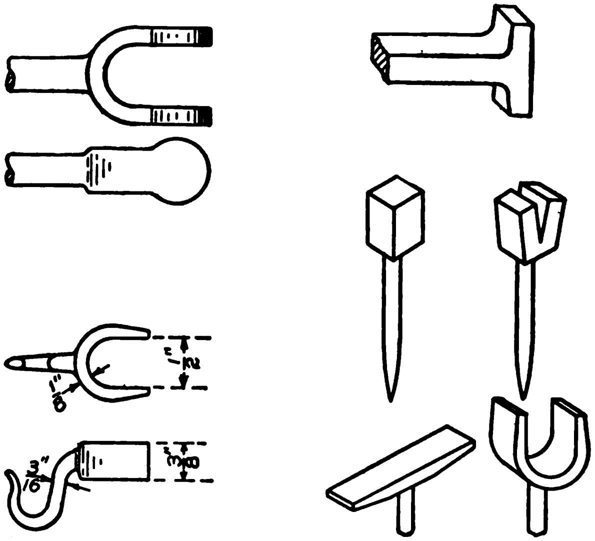

Fig. 104.

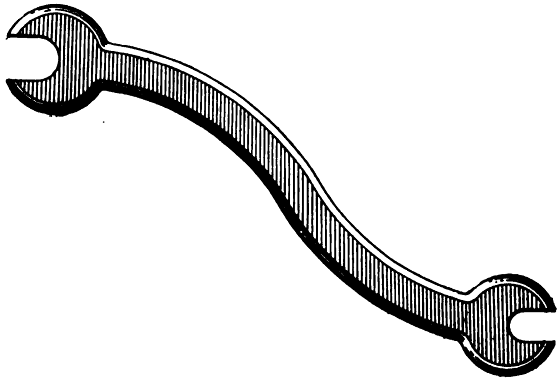

Fig. 105.

Socket Wrenches are made in several ways. The easiest way in "hurry up" work is the method illustrated in Fig. 107. A stub is forged to the same size and shape as the finished hole is to be, and a ring, bent up of thin flat iron, welded round this stub. When finishing the socket, a nut or bolt head of the same size that the wrench is intended to fit, should be placed in the hole and the socket finished over this, between swages. A better way of making wrenches of this kind is to make a forging having the same dimensions as the finished wrench with the socket end left solid. The socket end is then drilled to a depth slightly greater than the socket is wanted. The diameter of the drilled hole should be as shown in Fig. 108, equal to the shortest diameter of the finished hole. After drilling, the socket end is heated and a punch, of the same shape as the finished hole,

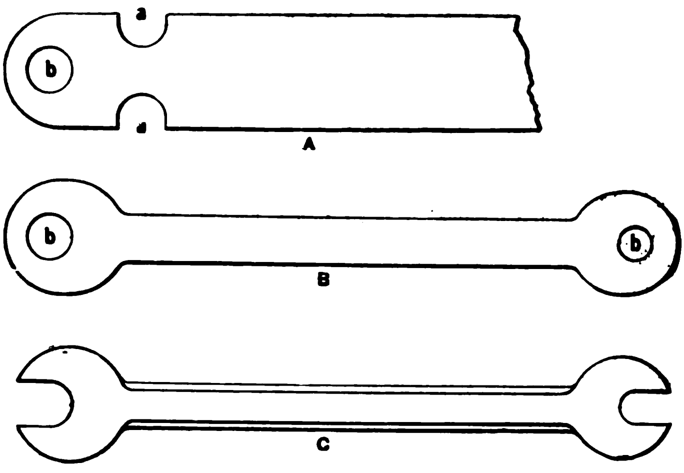

Fig. 106.

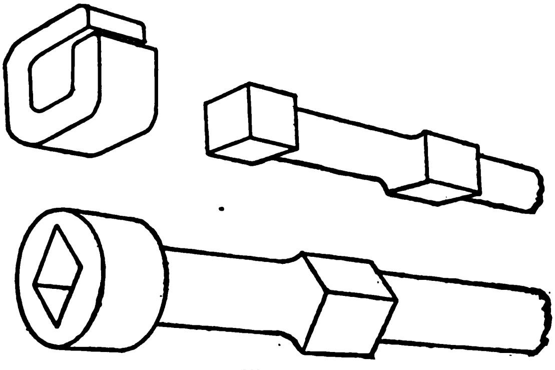

Fig. 107.

driven into it. The end of the punch should be square across and the corners sharp. As the punch is driven in, it will shave off some of the metal around the corners of the hole and force it to the bottom, thus making it necessary to have the drilled hole slightly deeper than the finished socket.

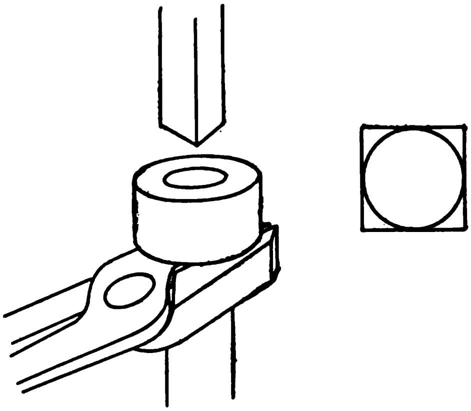
Fig. 108.

Ladle Shank. The ladle shank shown in Fig. 109 may be made in several ways. The ring may be welded up of flat stock and a round handle welded on with a T-weld. Or square stock may be taken, worked out and split as shown in Fig. 110, these split ends being afterwards welded to make the ring. Another method of making without any welds at all would be to split the stock as indicated in Fig. 111 and work out in the same way that a weldless ring is made. The latter method would take more time but would make the sounder forging.

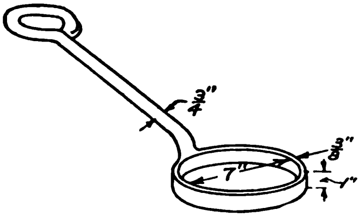

Fig. 109.

Molder's Trowel. The molder's trowel illustrated in Fig. 112 is a sample of a large class of forgings, having a wide, thin face with a comparatively small thin stem forged at one end. The stock used for the trowel would be about $\frac{1}{4}''$ × 1″. This is thick enough to allow for the formation of a ridge at R. Fig. 113 shows the general method employed. Two nicks are first made with fullers as illustrated at A and the stem drawn down, roughly, to size. This stem is then bent up at right angles and forged to a square corner as illustrated at B, in the same general manner as the square corner of a bracket is formed. When flattening out the blade in order to leave the ridge shown at R, Fig. 112, the work should be held as shown at C, Fig. 113. Here the handle is held pointing downward and against the side of the anvil. By striking down on the work and covering the part directly over the edge of the anvil with the blows, all the metal on the anvil will be flattened down. By swinging the piece around into a reversed position, the other edge of the blade is then thinned down. This leaves the small triangle shown by the dotted lines

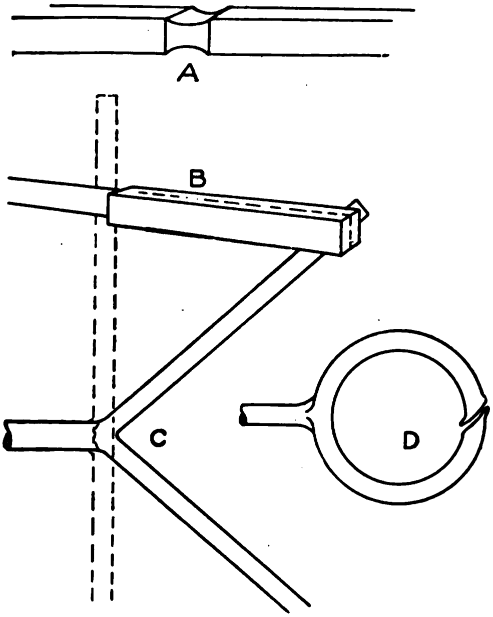

Fig. 110.

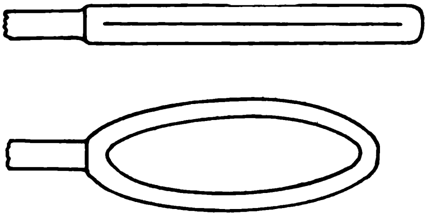

Fig. 111.

unworked and forms the ridge shown at R. The same result could be obtained by placing the work flat on the anvil face and using a set hammer.

TOOL STEEL WORK.

Tool Steel. Although not strictly true technically, for ordinary purposes tool steel may be considered simply a combination of iron and carbon. The more common grade contains perhaps 1 per cent of carbon. Machine steel and wrought iron do not contain this element carbon to any great extent. If a piece of wrought iron or machine steel be heated red hot and suddenly cooled, the metal remains practically as it was before heating, but if a piece of tool steel be subjected to this treatment, it becomes very hard and brittle. By a modification of this heating and cooling, almost any degree of hardness may be imparted to the steel. When tool steel is heated red hot and then suddenly cooled, becoming very hard, the process is known as *Hardening.* For more detailed explanations of hardening, tempering, etc., the student is referred to "Tool Making", as merely general statements and explanations will be given here. If two pieces of tool steel be heated, one to a comparatively high heat and one to a lower heat and the two pieces suddenly cooled in water, if the ends be then snapped off, a decided difference will be noticed in the fractures. The piece cooled from the

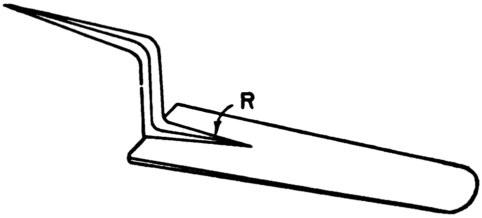

Fig. 112.

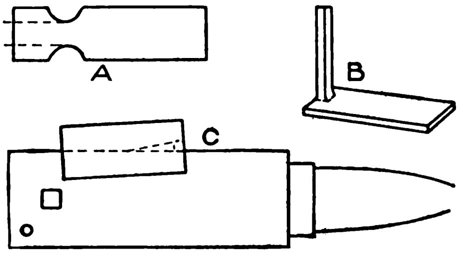

Fig. 113.

higher temperature will have a very coarse grain, while that cooled from the lower temperature will have a finer grain. Two things are fixed when hardening a piece of tool steel—hardness and grain. The hardness depends upon the rapidity with which the steel is cooled. The more rapid the cooling, the harder the steel. The grain depends upon the heat from which the steel is cooled. There is only one heat from which the steel may be cooled and have the proper grain. This heat is known as the *hardening heat.* A piece of steel when cooled from this hardening heat has an extremely fine silky looking grain and is left very hard and brittle.

Hardening. The *hardening heat* varies with the amount of carbon the steel contains, the greater the percentage of carbon, the lower the hardening heat.

To determine the hardening heat, a bar ¼″ or ⅜″ square is heated to a good red heat on one end, and cooled in cold water. This end is then tested, if too hard to file it has been hardened, and the heat from which it was cooled was either the proper hardening heat or some higher heat. If the end can be filed it was cooled from some heat below the hardening heat. If the end proves to be soft it should be rehardened by cooling from a higher heat, if hard it should be broken off and the fracture examined. If the grain of the broken end is very fine the steel is properly hardened, if coarse, it was heated too hot and the end should be rehardened at a lower heat. The experiment should be repeated until the operator is able to give the steel a very fine grain every time. Any variation either above or below the hardening heat will make the grain coarse. A temperature lower than the critical heat will not make the steel as coarse in structure as a temperature correspondingly higher, but there will be some difference.

Hardening Baths. Various baths are used for cooling steel when hardening, on account of the different rates at which they cool the heated metal. An oil bath is used when the steel is wanted tougher and not excessively hard, as the oil cools the steel slower than water. Brine or an acid bath are used when the steel is wanted very hard, as they absorb heat more rapidly than water. For excessively hard work mercury, or quicksilver, is sometimes used, as it absorbs the heat very rapidly.

General Laws of Hardening. The two simple general facts of hardening that must be remembered are as follows: First, the heat from which the steel is cooled determines the grain; secondly, the rapidity of cooling determines the hardness, everything else being equal, the more rapid the cooling, the harder the steel.

Annealing. When steel is annealed it is softened. This is done by cooling the steel very slowly from the hardening heat, the cooling being done as slowly as possible. This cooling in some cases takes several days. As noted under hardening, the rapidity of cooling determines the final hardness of the steel and if the steel be cooled very slowly it will be left very soft; while if cooled rapidly, it will be left hard. This difference in the time taken to cool the steel is the only difference between hardening and annealing. Both should be done from the same heat. The details of various methods of annealing are described in "Tool Making".

Tempering. Tools which are simply hardened as described above are, with few exceptions, too brittle for use and it is necessary to reduce the brittleness. This process is known as tempering. Tools are always left as hard as it is possible to leave them and still have them tough enough for the work for which they are intended. In reducing the brittleness of the steel, some of the hardness is of necessity taken out and tempering is therefore sometimes spoken of as a reduction of the hardness, but it is in reality, merely a reduction of the brittleness. After a tool or piece of steel has been hardened, some of the brittleness is taken out by a slight reheating to a low temperature. These temperatures vary from 200° F., to about 650° F. These temperatures are determined in various ways. The simplest and perhaps the most commonly used, is to polish the steel after it has been hardened and then reheat [illegible] he part to be tempered until the surface shows a certain color.

If any bright piece of iron or st [illegible] when a tempe [illegible]
of about 400° F is reached, the surf [illegible]
temperature is increased this yello [illegible]
it is a decided brown. When 60 [illegible]
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formed on the surface of the s [illegible]
hardness, merely showing to w [illegible]

Tempered tools may be divided into two general classes: First, those which have one edge only tempered; second, those which are tempered throughout. To the first class belong most lathe tools, cold chisels, etc. To the second class, taps, dies, milling cutters, etc. When tempering tools of the first class, considerably more of the tool is heated than is wanted hardened. The cutting edge is then hardened by cooling in water. The tool is then taken from the water, the hardened edge polished, and reheated by allowing the heat to "come down" from the body of the tool, which is still quite hot. Tools of the second class are first hardened by being heated to a uniform hardening heat and then cooled completely. The tool is then polished and the temper drawn by placing the steel either over the fire or on a piece of metal which has previously been heated red hot. It is absolutely essential that the steel should be heated to a uniform temperature when hardened. The parts to be hardened should show no difference whatever in color when being heated. If points or corners of tools are allowed to come to the hardening temperature before the body of the tool is hot, these overheated corners are almost sure to crack off. Absolute uniformity in heating to the proper hardening heat is necessary to insure success in hardening operations.

Lead Bath. To insure uniformity in heating, various methods are used, and when the work is done on a large scale the heating is generally done in a furnace fired with gas. Another common method is to heat the steel in a bath of red hot lead. The lead is heated in a pot or crucible, to the hardening heat of the steel. The top of the lead is covered with powdered charcoal or coal to prevent the formation of the slag or dross on top. When steel is heated in lead it must be perfectly clean, dry, and free from rust.

TOOL FORGING AND TEMPERING.

Forging Heat. Before attempting any work with tool steel, a piece of scrap steel is to be experimented with, heated and hardened several times at various heats until the manipulator is sure of the effect of the various heats upon the grain of the steel. The steel should also be experimented with to determine just how high a heat it will stand. When heavy forging is to be done, *i. e.*, when the first rough shaping is done upon a tool, a comparatively high heat should be used. The steel should be forged at about what might be called a good yellow heat. The lighter hammering, when finishing, should be done at a lower heat, about the hardening heat. Very little, if any, hammering should be done below the hardening heat. If the grain of the steel has heen raised by too high a heat, it can generally be quite decidedly reduced by a little hammering at some heat above the hardening temperature.

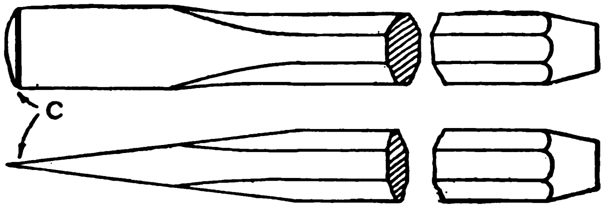

Fig. 114.

Cold Chisels. The stock should be heated to a good yellow heat and forged into shape and finished as smoothly as possible. When properly forged, the end or cutting edge will bulge out as shown in Fig. 114. It is a good plan to simply nick this end across at the point where the finished edge is to come and then after the chisel has been tempered, this nicked end may be broken off and the grain examined. Whenever possible, it is a good plan to leave an end of this sort on a tool that may be broken off after the tempering is done. When hardening, a chisel should be heated red hot about as far back from the cutting edge as the point A, Fig. 115. Care must be taken to heat slowly enough to keep the part being heated at a uniform temperature throughout. If the point becomes overheated, it should not be dipped in water to cool off, but allowed to cool in the air to below the hardening heat and then reheated more carefully. When properly heated, the end should be hardened by dipping in cold water to the point B. As soon as the end is cold, the chisel should be withdrawn from the water and the end polished bright by rubbing with a piece of emery paper. The part of the chisel from A to B will still be red hot

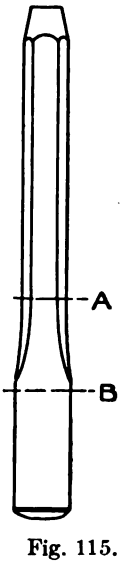

Fig. 115.

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ASTOR, LENOX AND
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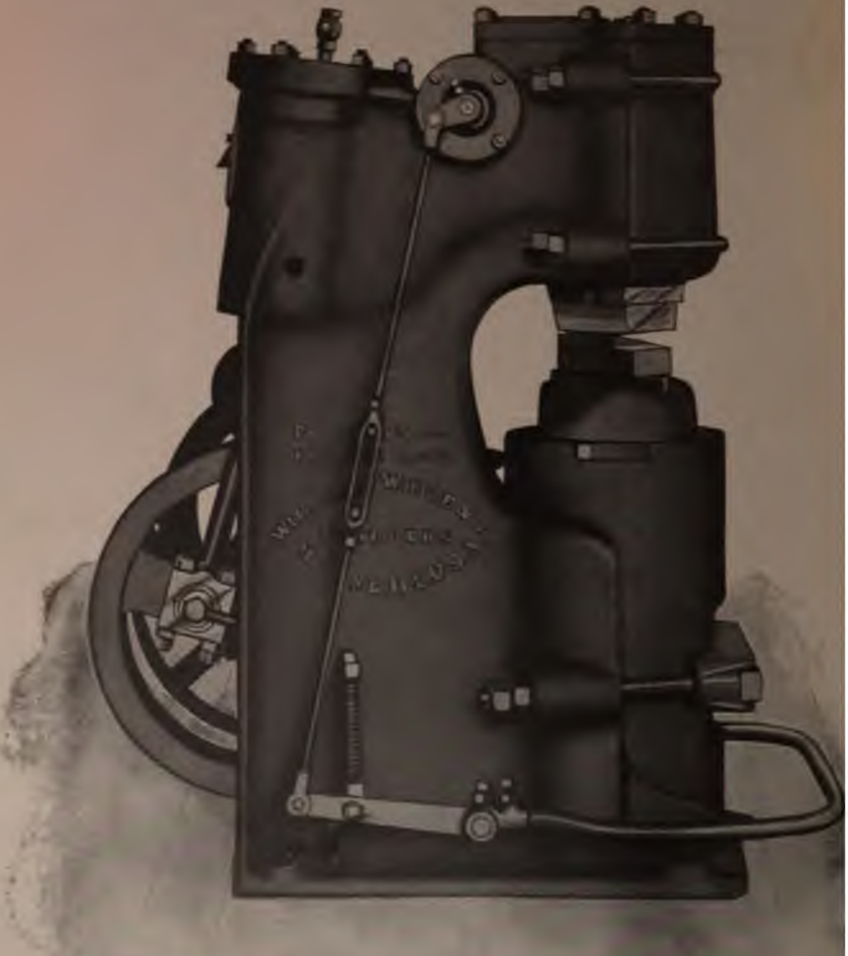


80-POUND HAMMER WITH DETACHED ANVIL.

Williams, White and Co.

and the heat from this part will gradually reheat the hardened point. As this cold part is reheated, the polished surface will change color showing at first yellow, then brown, and at last purple. As soon as the purple (almost blue color) reaches the nick at the end, the chisel should be completely cooled. The waste end may now be snapped off and the grain examined. If the grain is too coarse the tool should be rehardened at a lower temperature, while if the metal is too soft, and the end bends without breaking, it should be rehardened at a higher temperature.

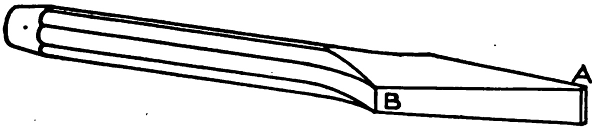


Fig. 116.

Cape Chisel. This is a chisel used for cutting grooves, key seats, etc. The end A should be wider than the rest of the blade back to B, Fig. 116. The chisel is started by thinning down B with two fullers, or over the horn of the anvil as shown at A, Fig. 117. The end is then drawn out and finished with a hammer or flatter in the manner illustrated at B. A cape chisel is given the same temper as a cold chisel.

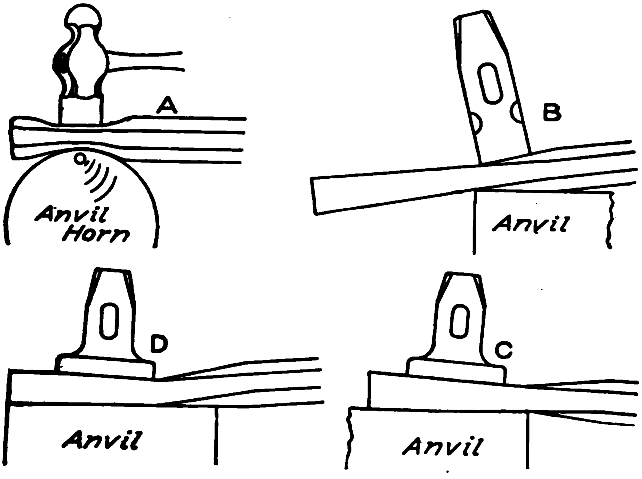


Fig. 117.

Square and Round Nose Chisels. These two chisels, the ends of which are shown in Fig. 118, are forged and tempered in practically the same way as the ordinary cape chisel, the only difference being in the shape of the ends. Round nose cape chisels are sometimes used for centering drills and are then known as centering chisels.

Lathe Tools. The same general forms of lathe tools are used in nearly all shops, but the shapes are altered somewhat to suit individual tastes.

Right Hand and Left Hand Tools. Many lathe tools are made in pairs and are called right and left hand tools. If a tool is made in such a way that the cutting edge comes toward the left hand as the tool is held in position in the lathe, it is known as a *right hand tool, i. e.,* a tool which begins a cut at the right hand end of the piece and moves from right to left is known as a right hand tool. The one commencing at the left hand end and cutting toward the right would be known as a *left hand tool.* The general shape of right and left hand tools for the same use is generally the same excepting that the cutting edges are on opposite sides.

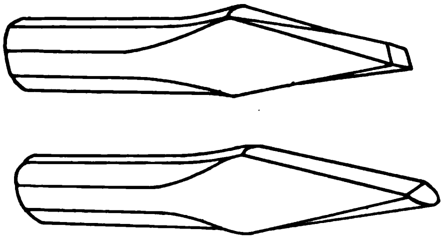


Fig. 118.

Clearance. When making all lathe tools, care must be taken to see that they have proper clearance, *i. e.,* the cutting edge must project beyond or outside of the other parts of the tool. In other words, the sides of the tool must be undercut or slant downwards and backwards away from the cutting edge. This is illustrated in the section A B of Fig. 119, where the lower edge of the tool is made considerably

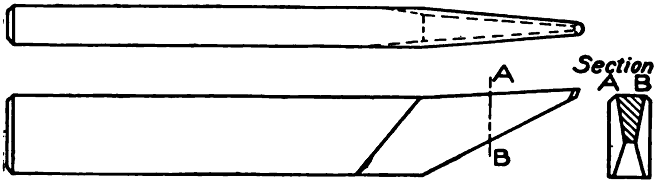


Fig. 119.

thinner than the upper edge, in order to give the proper clearance.

Round Nose and Thread Tools. These tools are practically alike excepting for a slight difference in the way the ends are ground. The general shape is shown in Fig. 119. When hardening, the tools should be heated about as far as the line A, Fig. 120, and cooled up to the line B. The temper is then drawn in the same general way as described for tempering of cold chisels excepting that when a light yellow color shows at the cutting edge the tool is cooled for the second time. All lathe tools are given practically the same temper. Sometimes tools are left much harder. In one quite well known plant the tools are simply reheated until the water evaporates from the cutting end, indicating a reheating to a temperature of about 200°F.

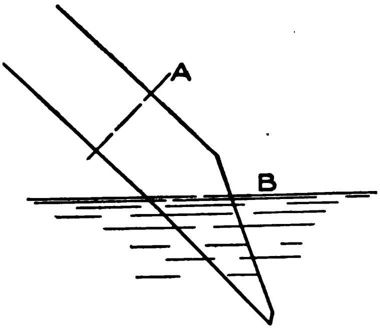


Fig. 120.

Cutting off Tools are forged with the blade either on one side or in the center of the stock. The easier way to make them is to forge the blade with one side flush with the side of the tool. Such a tool is shown in Fig. 121. The cutting edge, A, the extreme tip of the blade, should be wider than any other part of the thinned end, B. In other words, this edge should have clearance in all directions as indicated in the drawing. The clearance angle at the end of the tool as shown in the sketch, is about correct for lathe tools. For heavier tools for the planer, the angle should be as shown by the line X X. When hardening, the end of the tool should be heated to about point C C and cooled to about the line D D, and the temper drawn as described for the round nose tool. Tools may be forged in the general way shown in Fig. 122. The tool is started by making a fuller cut as shown

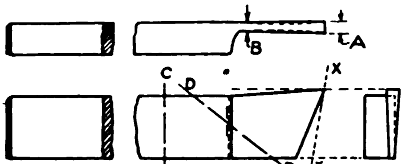


Fig. 121.

at A. After roughly shaping, the end is trimmed off with a hot chisel along the dotted line at C. Great care must be taken to see that the blade of the tool has proper clearance in all directions.

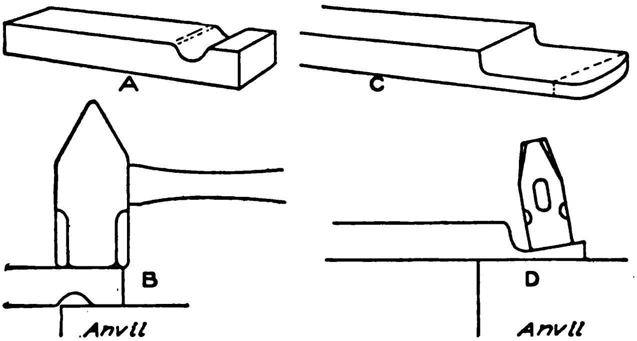


Fig. 122.

When a tool is wanted with a blade forged in the center, it should be first started by using two fullers instead of one, then making two cuts, one on each side of the stock, in place of the single cut shown at A.

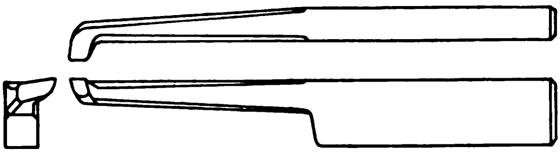


Fig. 123.

Boring Tool. The general shape of this tool is shown in Fig. 123. The length of the thin end depends upon the depth of the hole in which the tool is to be used and as a general rule should be made as short and thick as possible, in order to avoid springing. The tool may be started in the same general way as the cutting off tool, the fuller cut being made on the edge of the stock instead of on the side. The cutting edge of the tool is at the end of the small "nose," and this "nose" is the only part which should be tempered.

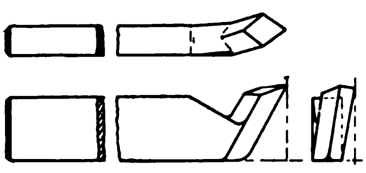


Fig. 124.

Diamond Points. These tools are made in a variety of modifications of the shape shown in Fig. 124. There are various methods used for shaping them, one of which is illustrated in Fig. 125. The shape is started as indicated at A. After the nick has been made as shown, the end of the tool is shaped as shown by the dotted lines, the blows coming in the direction of the arrow. Further shaping is done as indicated at B. To square up the end of the nose of the tool, it is worked backward and forward as indicated at C. The tool is finished by trimming off the end to the proper angle with a hot chisel and touching it up with a set hammer When hardened it should be dipped about as shown at D.

Side Tools or side finishing tools as they are sometimes called, are generally made in about the shape shown at F, Fig. 126. The tool

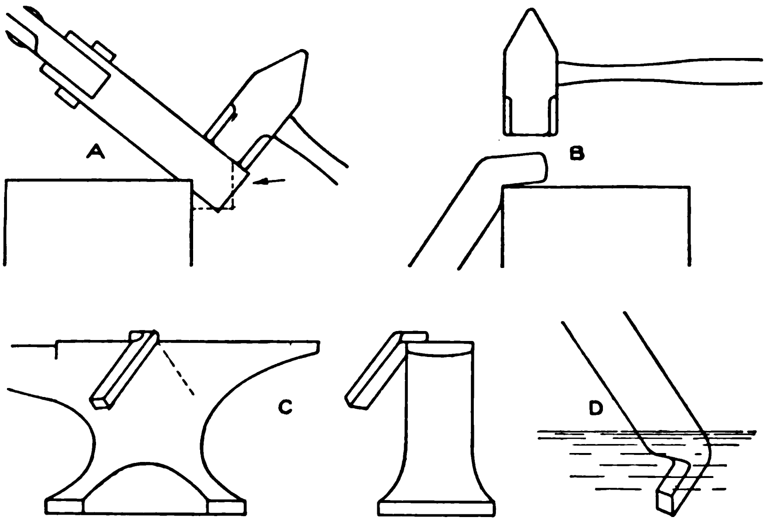


Fig. 125.

may be started by making a fuller cut as shown at A. The end x is then drawn out with a fuller into the shape B. After smoothing up with a set hammer the blade is trued into shape along the dotted lines at C. The tool is finished by giving the proper "*offset*" to the top edge of the blade. This is done by placing the tool flat side down with the blade extending over, and the end of the blade next the shank about $\frac{1}{8}''$ beyond, the outside edge of the anvil. A set hammer is placed on the blade close up to the shoulder and slightly tipped, so that the face of the hammer touches the thin edge of the blade only, as illustrated at D. One or two light blows with the sledge will give the necessary offset and after touching up the blade, the tool is ready for tempering. When heating for hardening, the tool should be placed in the fire with

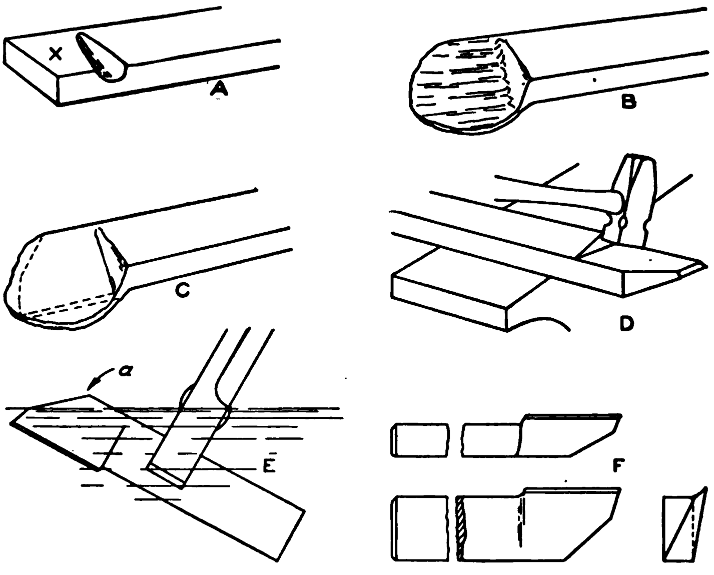


Fig. 126.

the cutting edge *up*. In this way it is more easy to avoid overheating the edge. The hardening should be done by dipping the tool in water as illustrated at E, only the small part A being left above the surface. The tool is taken from the water, quickly rubbed bright

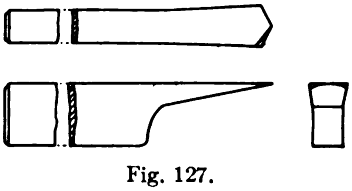


Fig. 127.

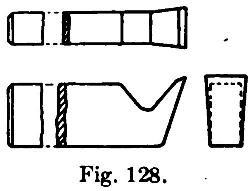


Fig. 128.

on the flat side, and the temper drawn until the cutting edge shows a light yellow. The same color should show the entire length of the cutting edge. If the color shows darker at one end, it indicates that that end of the blade was not cooled enough and the tool should be rehardened, this time dipping the tool in such a way as to bring that end of the blade which was too soft before, deeper in the water.

Centering Tool. The centering tool shown in Fig. 127 is used for starting holes on face-plate and chuck work. The end may be shaped by making a fuller cut and then flattening out the metal, trimming the cutting edge to shape with the hot chisel.

Forming Tools for Turret Lathes are sometimes forged up in the same general shape as above and tempered like other lathe tools.

Finishing Tool. This tool, Fig. 128, may be started either with a fuller cut or in the same way as the diamond point. The end is then flattened out and shaped with a set hammer as shown in Fig. 129. This generally leaves the end bent out too nearly straight, but it may be easily bent back into shape as indicated at B. This bending will probably leave the point something like C. A few blows of the hammer at the point indicated by the arrow will give the tool the shape as at D. The cutting edge should be tempered the same as other lathe tools. For planer and shaper tools of this shape, the end should be more nearly at right angles to the edge of the tool, making an angle of about six or eight degrees less than the perpendicular. In other words, the tool should have less end rake.

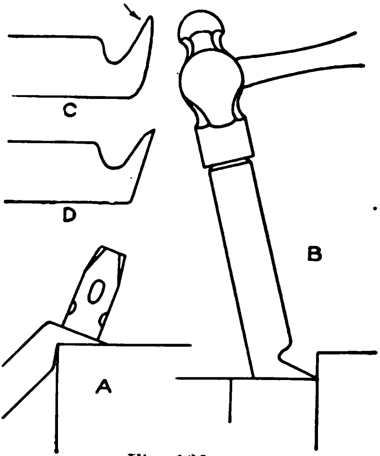


Fig. 129.

Flat Drills need no particular description as to forging and shaping. The size of the drill is determined by the width of the flat end, this being the same size as the hole the drill is intended to bore. If this dimension were one inch, the drill would be known as a one-inch drill. The drill should be made somewhat softer than lathe tools, the temper being drawn until a light brown shows at the cutting edge.

Springs are generally tempered in oil. The spring is heated to a uniform hardening heat and hardened by cooling in oil. The temper is drawn by holding the spring, still covered with oil, over the flame of the forge, and heating until the oil burns over the entire spring. If the spring is not uniform in section throughout, it is generally advisable, while heating it, to plunge every few seconds into the oil bath, taking it out instantly and continuing the heating. This momentary plunge tends to equalize the heat by cooling the thinner parts.

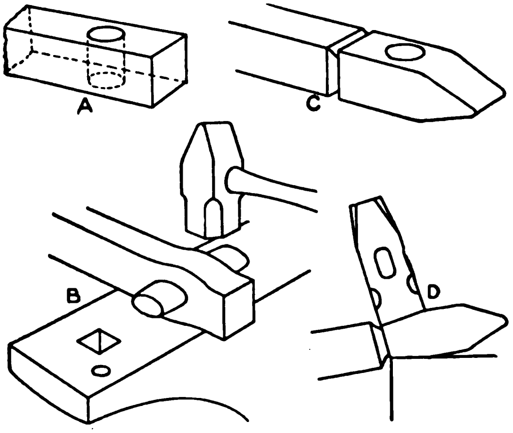


Fig. 130.

Lard oil or fish oil are generally used as mineral oil is too uncertain in composition. The above method of tempering is known as *blazing off*, the blazing point of the oil being used to indicate the temperature in place of the color of the scale. The same results could be obtained by polishing the spring and heating until it turned blue.

Hammers. When making a hammer the stock should be taken large enough to make the largest part of the hammer without any upsetting. As a general rule the hammer is forged on the end of a bar and finished as completely as possible before cutting off.

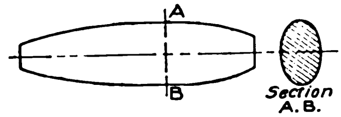


Fig. 131.

Riveting Hammer. About the easiest hammer to shape is the riveting hammer shown at D, Fig. 4. This hammer, as well as all other hammers, is started by first punching the hole for the eye as shown at A, Fig. 130. When the eye is punched the stock is generally bulged out sideways and in order to hold the shape of the eye while flattening down this bulge, a drift pin such as shown in Fig. 131 is used. This pin is made larger in the center and tapering at both ends. The center or larger part of the pin has the same shape as the finished eye of the hammer. This pin is driven into the punched hole and the sides of the eye forged into shape as illustrated at B, Fig. 130. After the eye has been properly shaped, the next step is to shape down the tapering pene leaving the work, after a nick has been made around the bar where the face of the hammer will come, as shown at C. The end of the hammer toward the face is then slightly tapered in the manner indicated at D. After the hammer has been as nearly as possible finished, it is cut from the bar and the face trued up. For tempering, the whole hammer is heated to an even hardening heat. The hammer is then grasped by placing one jaw of the tongs through the eye. Both ends are tempered, this being done by hardeneng first one end and then the other. The small end is first hardened by dipping in the water as shown at Fig. 132. As soon as this end is cooled the position of the hammer is instantly reversed and the face end hardened. While the large end is in the water the smaller end is polished and the temper color watched for. When a dark brown scale appears on the small end the hammer is again reversed bringing the large end uppermost and the pene in the water. The face end is then polished and the temper drawn. If the large end is properly hardened before the temper color appears on the small end, the hammer may be taken completely out of the water, the large end polished, and the colors watched for on both ends at once. As soon as one end shows the proper color it is promptly dipped in water, the other end following as soon as the color appears there, but under no circumstances should the eye be cooled while still red hot. For some special work hammer faces should be left harder, but for ordinary use the temper as given above, is very satisfactory.

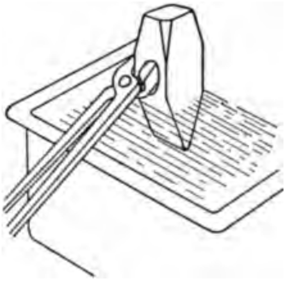


Fig. 132.

Ball Pene Hammer. The general method of making this hammer is illustrated in Fig. 133. After punching the hole, the hammer is roughed out by using the fullers as shown at A and B. The ball end is then rounded up, the octagonal parts shaped with the fullers and the hammer cut from the bar, ground and tempered. Ball pene hammers may be made with a steam hammer in practically the same way as described above, excepting that round bars of steel should be substituted for the fullers.

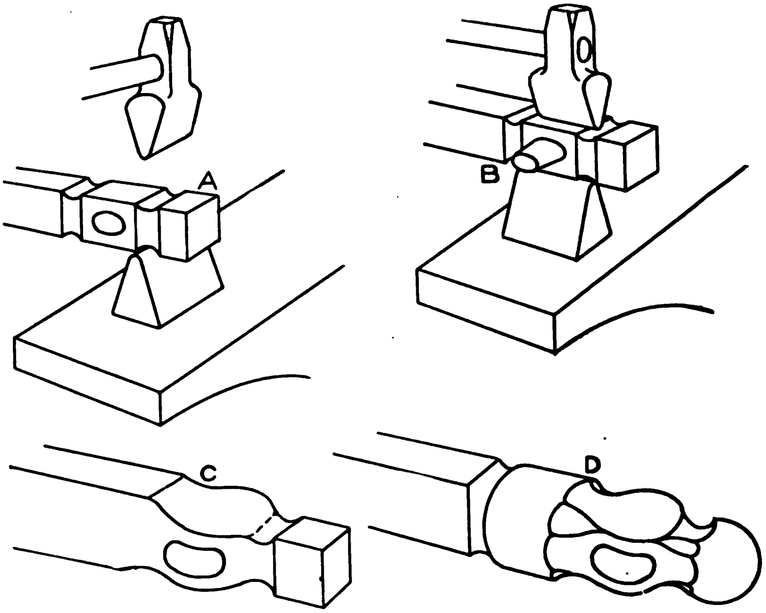


Fig. 133.

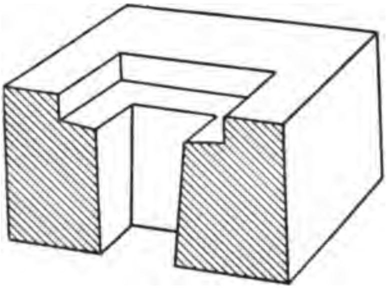


Fig. 134.

Blacksmith's Tools such as cold chisels, hot chisels, set hammers and flatters are made in much the same way as hammers. The wide face of the flatters may be upset by using a block such as is shown in Fig. 134. The heated end of the tool is dropped into the hole in the block and the face upset into the wide shallow opening. Swages may also be worked up in this way.

Self-hardening Steel is used to a large extent in modern practice for lathe tools, much being used in the shape of small square steel held in special holders. Such a tool is illustrated in Fig. 135. Self-hardening steel, as its name indicates, is almost self-hardening in nature, generally the only treatment that is required to harden the steel being to heat it red hot and allow it to cool. Sometimes the steel is cooled in an air blast or is dipped in oil. It is not necessary to "draw the temper". The self-hardening quality of steel is given to it by the addition of Chromium, Molybdenyum, Tungsten, or one of that group of elements, in addition to the carbon which ordinary tool steel contains. Self-hardening steel is comparatively expensive, costing from 40 cents and upwards per pound, some of the more expensive grades costing $1.00 or so. When in use, self-hardening steel will stand a much higher cutting speed than the ordinary so-called carbon steel. For this reason it is much more economical to use, although its first cost is higher. Self-hardening steel cannot be cut with a cold chisel and must be either cut hot or nicked with an emery wheel and snapped off. Great care must be used in forging it, as the range of temperature through which it may be forged is comparatively slight, running from a good red heat to a yellow heat. Some grades of self-hardening steel may be annealed by heating the steel to a high heat in the center of a good fire and allowing the fire and the steel to cool off together. Steel which has been annealed in this way may be hardened by heating to the hardening heat and cooling in oil.

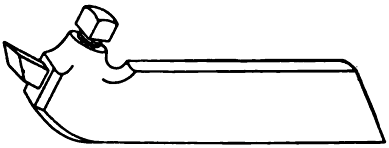


Fig. 135.

Taylor-White Process. This method of treating special grades of self-hardening steel was discovered some years ago by the men after whom it is named. It was found that if a piece of self-hardening steel be heated to a very high temperature (about the welding heat) and then suddenly cooled to about a low red heat, the steel would be in a condition to stand very much harder usage and take a much heavier cut. Steel treated in this way seemed to have the cutting edge of the tools almost burned or melted off and considerable grinding was necessary to bring them into shape. When put in use the edges would almost immediately be slightly rounded or crumble off, but after this slight breaking down of the cutting edge, the steel would stand up under excessively trying conditions of high speed and heavy cut. Tools of this character were of very little, or no, use for fine finishing, but were of great value for heavy and roughing cuts.

HEAVY FORGING.

Steam Hammer. An ordinary form of steam hammer is shown in Fig. 136. Its essential parts are an inverted steam cylinder, to whose piston rod the hammer head is attached, and the frame for carrying the whole. The hammer is raised by admitting steam beneath the piston. The blow is dealt by exhausting the steam from beneath the piston and admitting it above the same. The head is thus accelerated by gravity and the pressure of steam above the piston. The valve gear is so arranged that the intensity of the blow may be varied by changing the amount of steam admitted to the piston on its downward stroke. The steam admitted below on the same stroke forms a cushion for the absorption of the momentum of the head. In this way the lightest of taps and the heaviest of blows can be deliv-

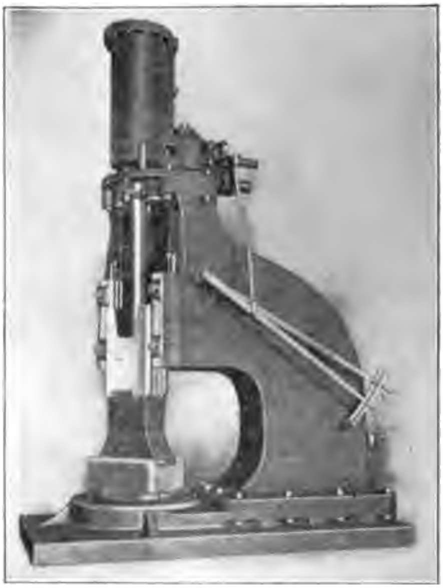


Fig. 136.

ered by the same hammer. These hammers are also made in a great variety of sizes. Steam hammers are rated by the weight of the falling parts, *i. e.*, the piston rod, ram or head, and hammer die. A hammer in which these parts weigh 400 lbs. would be called a 400 lb. hammer. Steam hammers are made in two distinct parts: the *frame*, carrying the hammer or ram, and the *anvil*, on which the hammer strikes.

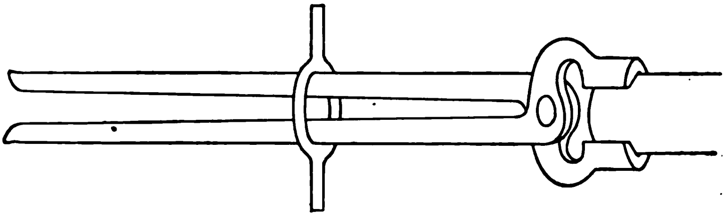


Fig. 137.

The frame is carried on a heavy foundation, and the heavy anvil, which is generally made of cast iron and fitted with a die block of tool steel, rests upon a heavier foundation of timber or masonry capped with a timber. The object of these separate foundations is to allow the anvil to give slightly under a blow without disturbing the frame. On very light power hammers the anvil and frame are sometimes made together.

Hammer Dies. The dies, as most commonly used with a steam

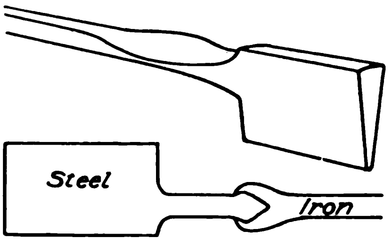


Fig. 138.

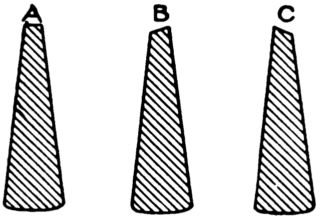


Fig. 139.

hammer, have flat faces. The best ones are made of tool steel. These dies may be made of tool steel and left unhardened, then when the dies become battered out of shape from use, they may be trued up and refaced without going to the trouble of annealing and hardening. Dies of gray cast iron and cast iron with a chilled face are also quite commonly used. Ordinary gray cast iron is used, particularly when special shaped dies are employed for welding and light bending.

Tongs for steam hammer work should always carefully be fitted and should grip the stock firmly on at least three sides. A quite common shape for tongs for heavy work is shown in Fig. 137. To hold the tongs securely on the work and to make it easier to handle them, a link is sometimes used of the shape shown. This is driven firmly over the handles of the tongs and the projecting ends are used as handles for turning the work.

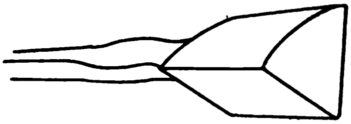


Fig. 140.

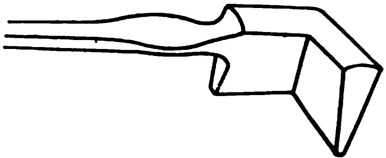


Fig. 141.

Hammer Chisels. The common shape for hot chisels for use under the steam hammer is given in Fig. 138. The handle and blade are sometimes made from one piece of tool steel. Sometimes the blade is made of tool steel and an iron handle welded on as shown in the sketch. The handle next to the blade should be flattened out to form sort of a spring which permits a little give when using the chisel. The edge of the chisel should be left square across and not rounding. The proper shape is shown at A, Fig. 139. Sometimes for special work the edge may be slightly beveled as at B or C. For cutting or nicking bars cold, a chisel similar in shape to Fig. 140 is sometimes used. This is made very flat and stumpy to resist the crushing effect of heavy blows. For cutting into corners a chisel similar in shape to Fig. 141 is sometimes used. For bent or irregular work the chisel may be formed accordingly. For cutting off hot stock the method used is about as illustrated in Fig. 142, *i. e.*, the work is cut nearly through as shown at A. The bar is then turned over and a thin strip of steel with square corners placed on top as shown at B.

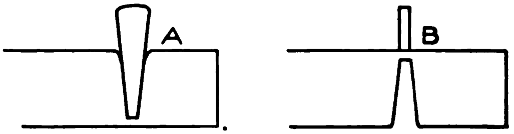


Fig. 142.

A quick heavy blow of the hammer drives this steel bar through the work and carries away the thin fin shown, leaving both of the cut ends clean and smooth.

Tools. The tools used for steam hammer work are generally very simple. Swages for finishing work up to three or four inches in diameter are commonly made in the shape shown in Fig. 143.

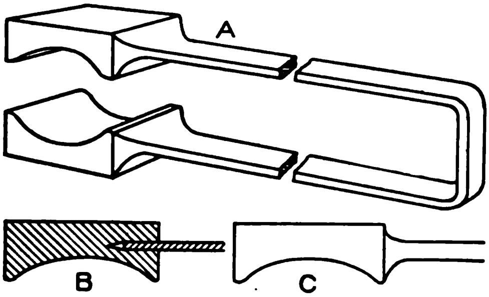


Fig. 143.

The handle is made in the shape of a spring and may be either made in one piece with the blocks and drawn out as shown at C, or may be inserted as shown at B. This sort of a tool is known as a spring tool. Another sort of swage sometimes used, is illustrated in Fig. 144, the

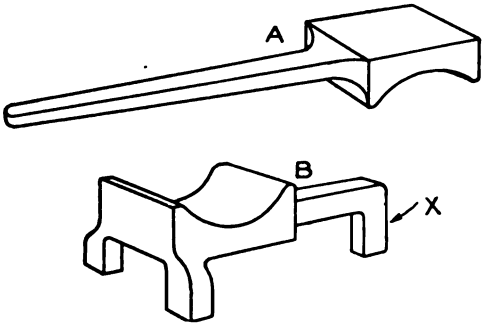


Fig. 144.

top swage at A, the bottom swage at B. This sort of a swage is used on a die block which has a square hole cut in its face similar to the hardy hole in an anvil. The short horn X, of the swage, fits into this hole, the other two projections coming over the side of the anvil block.

Tapering and Fullering Tool. The faces of the anvil and hammer dies are flat and parallel and it is, of course, impossible to finish tapering work smooth between the bare dies. This work may be done by using a tool similar to Fig. 145. Its method of use is shown in Fig. 146, the roughing being done with the round side down and the finishing with the flat side. Fullers used for ordinary hand forgings are seldom employed in steam hammer work. Round bars are used in their place in the manner illustrated in Fig. 147. If a nick is wanted on one side only, simply one round bar is used. Care must always be taken to be sure that the work is in the proper position before striking a heavy blow with the hammer. To do this the hammer should be brought down lightly on the work thus bringing the piece to a flat "bearing" for the first blow.

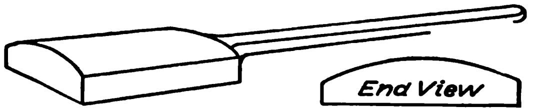


Fig. 145.

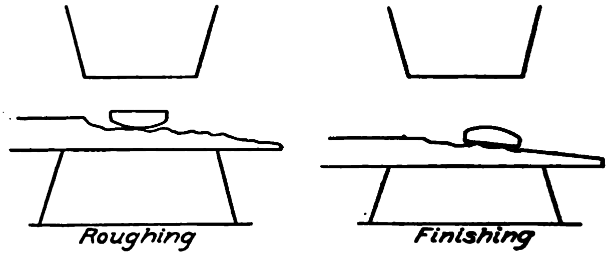


Fig. 146.

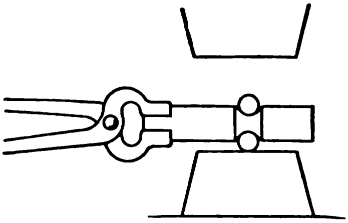
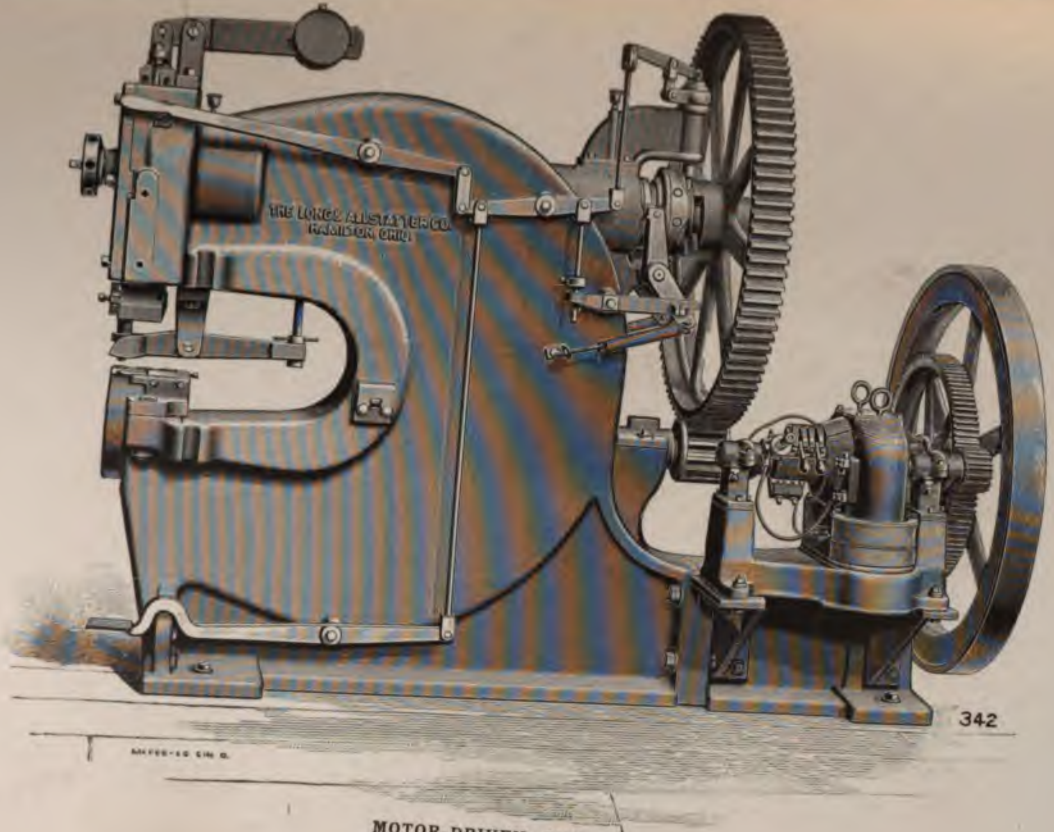


Fig. 147.

Squaring up Work. It frequently happens that work is knocked lopsided under the hammer, being worked up into some such shape as shown at A, Fig. 148. To correct this and bring the work up square, the bar should be put under the hammer and there knocked into shape B and then rolled in the direction indicated by the arrow until shaped as at C when it may then be worked down square and finished like D.

Crank Shafts. The crank shaft shown in Figs. 82 and 83 is quite



MOTOR-DRIVEN PUNCH.
The Long and Allstatter Co.

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a common example of steam hammer work. The stock is first worked as illustrated in Fig. 149, the cuts being on each side of the crank cheek. A special tool is used for this as illustrated. When the cuts are very deep, they should first be made with a hot chisel and then opened up with this spreading tool. With light cuts, however, both operations may be done with a spreading tool at the same time. Care must be taken, when flattening out the ends, to prevent any of the material from doubling over and forming a "cold shut". After the ends are hammered out, the corners next to the cheeks may be squared by using a block as shown in Fig. 85.

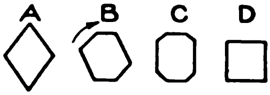

Fig. 148.

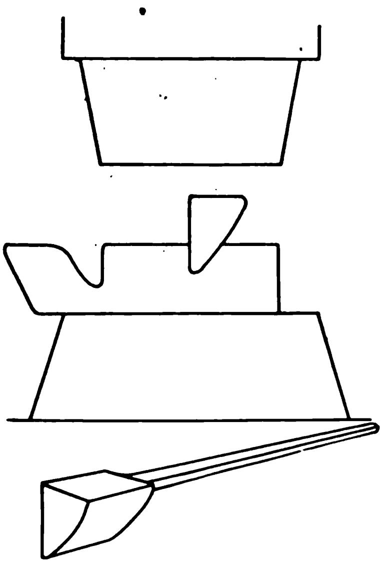

Fig. 149.

Connecting Rod: *Drawing out between the shoulders.* The forging illustrated in Fig. 80, while hardly the exact proportions of the connecting rod, is near enough the proper shape to give a good example of this kind of forging. The work is first started by making two cuts as illustrated in Fig. 150. The metal between the two cuts is then drawn out by using two steel blocks as shown in Fig. 151 until the metal is stretched long enough to allow the corners of the square ends to clear the edges of the hammer dies, when the work is done directly upon the bare die.

MISCELLANEOUS PROCESSES.

Shrinking. When iron is heated it expands and upon being cooled it contracts to about its original size. This property is utilized in doing what is known as *shrinking*. Fig. 152 shows a collar *shrunk* on a shaft. The collar and shaft are made separate, the hole through the collar being slightly less in diameter than the outside diameter of the shaft. The collar is then heated red hot and the heat causes the collar to expand, making the hole larger in diameter than the shaft. The collar, while still hot, is then placed on the shaft in proper position, and cooled as quickly as possible by pouring water on it. As the collar is cooled it contracts and squeezes, or locks, itself firmly in position. This principle of shrinking is used to a large extent where a firm, tight fit is wanted, the only objection being that it is rather difficult to take a piece off after it has once been shrunk into place.

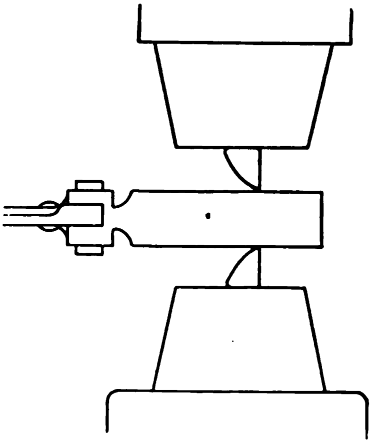

Fig. 150.

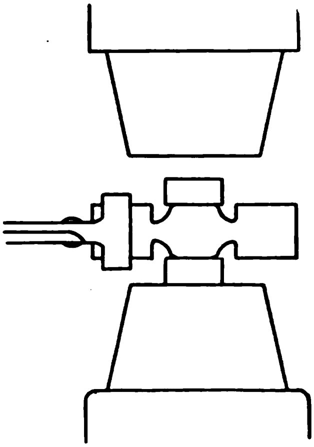

Fig. 151.

Brazing. When two pieces of iron or steel are welded together, they are joined by making the pieces so hot that the particles of one piece will stick to those of the other, no medium being used to join them. In brazing, however, the brass acts in joining two pieces of metal together in somewhat the same manner that glue does in joining two pieces of wood. Briefly the process is as follows: The surfaces

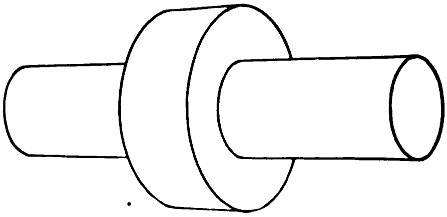

Fig. 152.

to be joined are cleaned, held together by a suitable clamp, heated to the temperature of melting brass, flux added, and the brass melted into the joint. The brass used is generally in the shape of "spelter". This is a finely granulated brass which melts at a comparatively low temperature. "Spelter" comes in several grades designated by hard, soft, etc., the harder spelters melting at higher heat but making a stronger joint. Brass wire or strips of rolled brass are sometimes used in place of spelter, brass wire in particular being very convenient in many places. A simple example of a brazed joint is shown in Fig. 153, where a flange is brazed to the end of a small pipe. It is not necessary in this case to use any clamps as the pieces will hold themselves together. The joint between the two should be made roughly. If a tight joint be used there will be no chance for the brass to run in. The joint should fit in spots but not all around. Before putting the two pieces together, the surfaces to be joined should be cleaned free from loose dirt and scale. When ready for brazing the joint is smeared with a flux (one part salammoniac, six or eight parts borax) which may be added dry or put on in the form of a paste mixed with water. The joint is then heated and the spelter mixed with flux sprinkled on and melted into place. Brass wire could be used in place of the spelter in the manner indicated, the wire being bent into a ring and laid round the joint as shown. Ordinary borax may be used as a flux, although not as good as the mixture used above. The heat should be gradu-

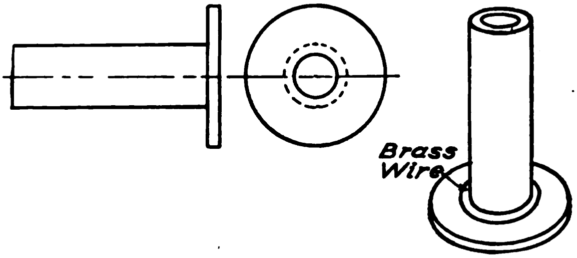

Fig. 153.

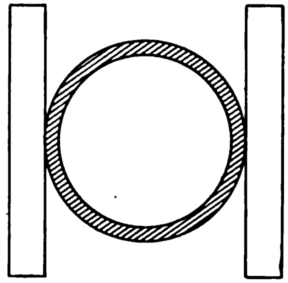

Fig. 154.

ally raised until the brass melts and runs all around and into the joint, when the piece should be lifted from the fire and thoroughly cleaned by scraping off the melted borax and scale. It is necessary to remove the borax, as it leaves a hard glassy scale which is particularly disagreeable if any filing or finishing has to be done to the joint. This scale may be loosened by plunging the work while still red hot, into cold water. Almost any metal that will stand the heat, may be brazed. Great care must be used in brazing cast iron to have the surfaces in contact properly cleaned to start with, and then properly protected from the oxidizing influences of the air and fire while being heated.

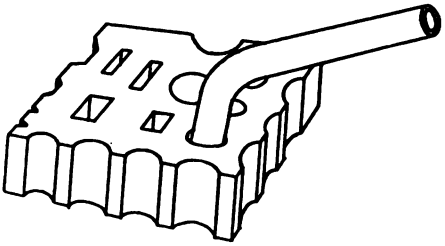
Fig. 155.

Annealing Copper and Brass may be done by heating the metals to a red heat and then cooling suddenly in cold water. When copper or brass is hammered to any extent, it becomes hard and springy and if it has to be further worked, it must be annealed or softened, otherwise it is almost sure to split.

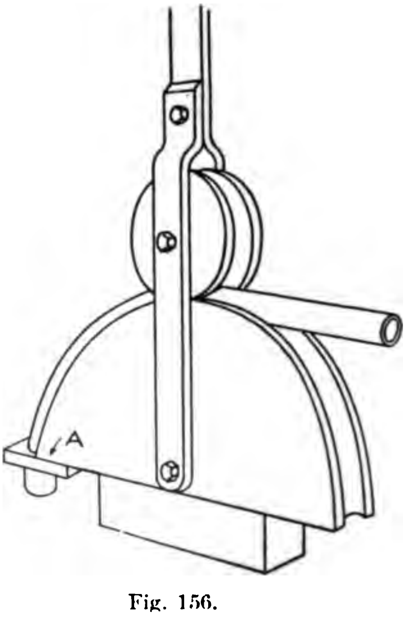

Fig. 156.

Bending Cast Iron. It is sometimes necessary to straighten a casting which has become warped or twisted. Cast iron may be twisted or bent to quite an extent if worked cautiously. The bending may generally be done at about the ordinary hardening heat of tool steel and should be done by a steadily applied pressure, not by blows. There is more danger of breaking the work by working it at too high a heat than by working at too low. As an example of how iron may be twisted, a bar of gray cast iron one inch square and a foot long may be twisted through about 90°, before it will break.

Case-Hardening. The essential difference between machine steel and tool steel is the amount of carbon that they contain. If carbon be added to machine steel it will be turned into tool steel. Sometimes articles are wanted very hard on the surface to resist wear and at the same time very tough to withstand shocks. If the piece be made of tool steel in order to be hard enough, it will be too brittle, and if made of machine steel in order to be tough enough, will be too soft. To overcome this difficulty the parts are made of machine steel and then the outside is carbonized or converted into tool steel to a slight depth, and this outside coating of tool steel then hardened. The process is known as *case-hardening*. The method used generally consists of heating the machine steel red hot in contact with something very rich in carbon, generally ground bone. The surface of the machine steel takes up or absorbs the carbon and is converted into tool steel. For more detailed information the reader is referred to "Tool Making".

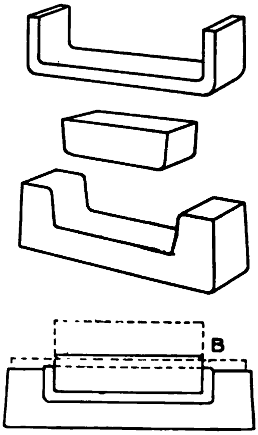

Fig. 157.

Pipe Bending. A piece of pipe when bent always has a tendency to collapse and if this collapsing can be prevented by keeping the sides of the pipe from spreading, a pipe may be successfully bent into almost any shape. One way of doing this would be to bend the pipe between two flat plates as shown in Fig. 154, the plates being the same distance apart as the outside diameter of the pipe. In bending large pipe, the sides are sometimes prevented from bulging by working in with a flatter. Where a single piece is to be bent, it may be done by heating the pipe and inserting one end in one of the holes in a swage block as shown in Fig. 155, the pipe being then bent by bearing down on the free end. As soon as a slight bend is made it is generally necessary to lay the pipe flat on the anvil and work down the bulge with a flatter. Where many pieces are to be bent, a grooved "jig" such as shown in Fig. 156 is sometimes used. The jig is of such a shape that the pipe is completely surrounded where it is being bent, thus not having any opportunity to collapse or bulge. Pipe is sometimes filled full of sand for bending. This helps to some extent. Care must be taken to see that the pipe is *full* and that the ends are solidly plugged. For bending thin copper tubing, it may be filled with melted rosin. This gives very satisfactory results for this character of work. After bending, the rosin is removed by simply heating the pipe.

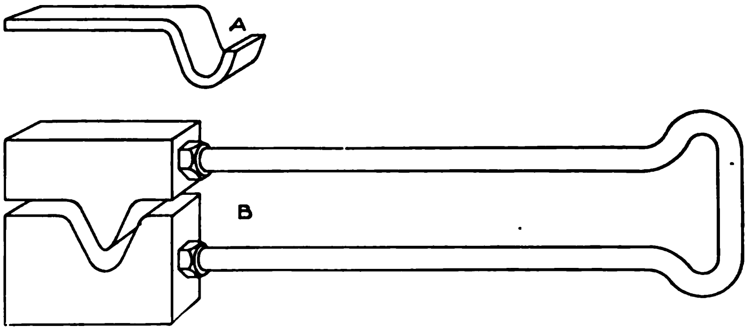

Fig. 158.

Duplicate Work. Where several pieces are to be exactly alike in a shop that is not equipped for special work, it is sometimes practical to use a "jig" for performing the operations. For simple bending the "jig" may consist of a set of cast-iron blocks. Fig. 157 illustrates a simple bend with the block used for doing the work. The work is done as shown at B. The piece to be bent is placed, as shown by the dotted lines, with the bending block on top. The bending is done by one or two strokes of the steam hammer. For convenience in handling, the bending blocks are sometimes held by a spring handle as shown in Fig. 158. The blocks in this case are for bending the hooks shown at A. The handle is simply a piece of

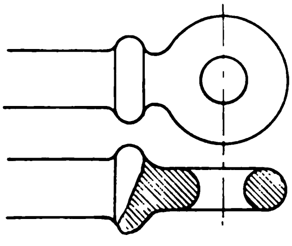

Fig. 159.

½″ round iron with the ends screwed into the cast-iron blocks and held firmly by the lock nuts shown. This makes a cheap arrangement for a variety of work, as the same handles may be used on various sets of blocks. Where a great number of pieces are to be made, these blocks or bending dies may be made of such a shape that they can be keyed on the steam hammer in place of the regular flat dies.

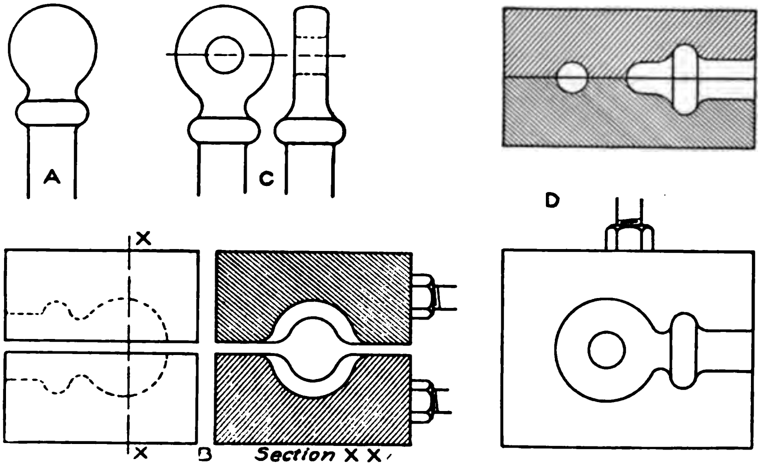

Fig. 160.

Die Forging. Pieces are sometimes shaped between formed steel dies where many are to be made exactly alike. An example of this sort of work is the eye bolt, Fig. 159. Round stock is used and is first shaped like A, Fig. 160. The shaping is done in the dies shown at B, which are simply two small blocks of tool steel fastened together with a spring handle, the inside faces of the blocks being formed to shape the piece as shown. The end of the bar is heated, placed between the die blocks and hammered until it takes the required shape, being turned through about 90° between each two blows of the steam hammer, and the hammering continued until the die faces just touch.

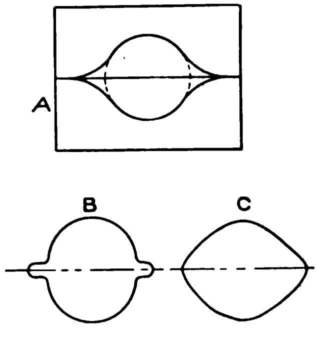

Fig. 161.

For the second step the ball is flattened to about the thickness of the finished eye and the hole punched under the steam hammer with an ordinary punch, leaving the work as shown at C. The final shaping is done with the finishing die D. This die is so shaped that when the two parts are together, the hole left is exactly the shape of the finished forging. In the first die it will be noticed that the holes do not conform exactly to the desired shape of the forging, being, instead of semicircular, considerably rounded off at the edges. This is shown more clearly in Fig. 161 at A, where the dotted lines show the shape of the forging, the solid lines the shape of the die. The object of the above is this: If the hole is semicircular in section, the stock, being larger than the smaller parts of the hole, after a blow will be left like B, the metal being forced out between the flat faces of the die and forming fins. When the bar is turned these fins are worked back and make a

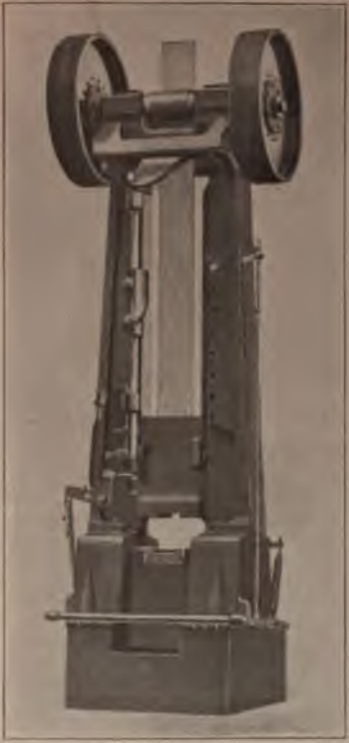
Fig. 162.

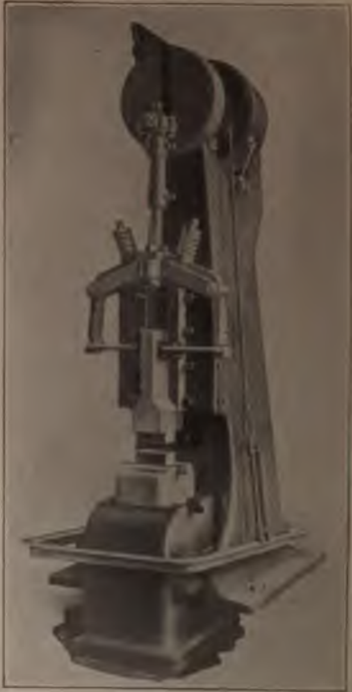
Fig. 163.

"cold shut". When the hole is a modified semicircle the stock will be formed like C, and may be turned and worked without danger of "cold shuts". Dies for this kind of work are sometimes made of cast iron. When made of tool steel it is sometimes possible to shape them hot. A "master" forging is first make of tool steel to exactly the shape of the required forging. The blocks for the dies are then forged with flat faces. These blocks are fastened to the handle and then heated red hot. The master forging is then placed between the dies and the dies hammered down tight over the forging. This leaves a cavity just the shape for the required forging.

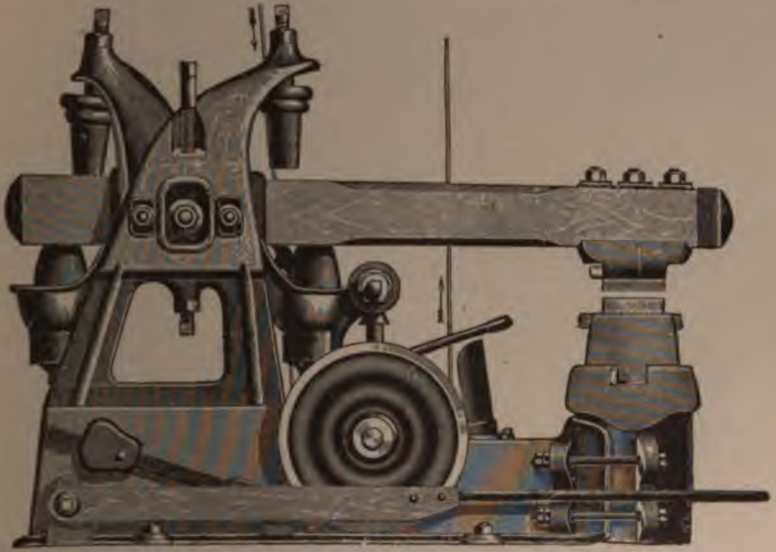

Fig. 164.

MANUFACTURING.

The manufacturing shop differs very essentially from the jobbing shop. In the latter shop very few forgings are made at the same time exactly alike, while in manufacturing, each forging is generally duplicated a large number of times and special machines are used for doing the work.

Drop Forges are used for quickly forming complicated shapes out of wrought iron or steel. They consist, as the name indicates,

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of a head that may be "dropped" from any desired height upon the piece to be shaped. The head of the drop and the anvil are in the form of dies. As they come together the metal is forced to flow so as to fill the interstices and thus take on the form desired. In drop forging the metal must be heated to a high temperature so as to be in a soft and plastic condition.

A common type of drop hammer used for this kind of work is is shown in Fig. 162. The hammer in this case is fastened to a board and is raised by the friction rollers at the top of the frame being pressed against the board. When the hammer reaches the top of the frame it is dropped by releasing the rollers from the board. This may be done automatically or by a foot treadle. Drop hammers are also built in the same general way as steam hammers. Dies for drop forging generally consist of a roughing or breaking-down die where the rough stock is first given approximately the desired shape and a smoothing die when the finishing is done. These dies have in their faces, holes of the same shape as the required forging.

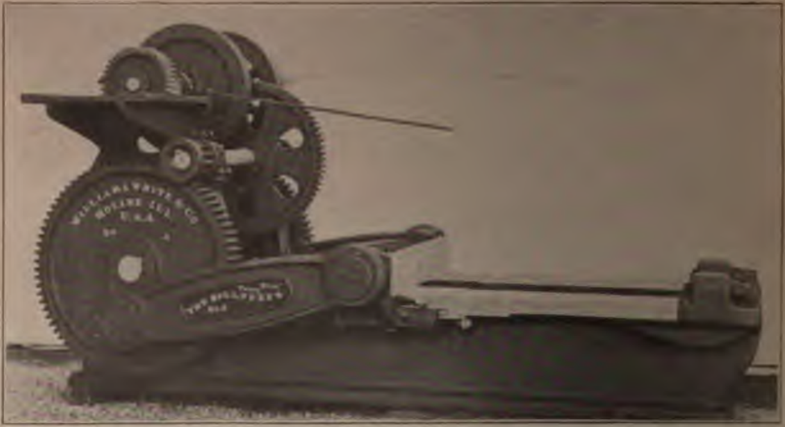

Fig. 165.

Power Hammers. Another tool which is used to quite a large extent in manufacturing as well as in the jobbing shop is the power hammer. This is made in several different types and is used where a quick, rapid blow is wanted. These hammers are run by belts. Two general types are shown in Figs. 163 and 164. The first is known as a justice hammer. The second is a Bradley. Shaped dies are frequently used on these hammers.

Bulldozer. This is a tool used for bending and consists of a heavy cast-iron bed with a block or bolster at one end, and a moving head which slides back and forth on the bed. A common type is shown in Fig. 165. Heavy dies are clamped against the bolster and on the moving head, of such a shape and in such a way that when the moving head is nearest the bolster, the shape left between the two dies is exactly the shape to which it is desired to bend the stock. In operation, the moving head slides back and forth on the bed. The bar to be bent is heated and placed between the dies when the head is farthest from the bolster. A clutch is then thrown in and the head moves forward to the bolster, bending the iron as it goes.

Presses serve the same purpose as drop hammers. They do the work more slowly, however. The class of work is, in some respects, the same. The principal difference lies in peculiarities of shape that require different time intervals for the flow of the metal. Where the shape is such that the metal must move slowly in order to acquire its new shape or fill the die, the press should be used.

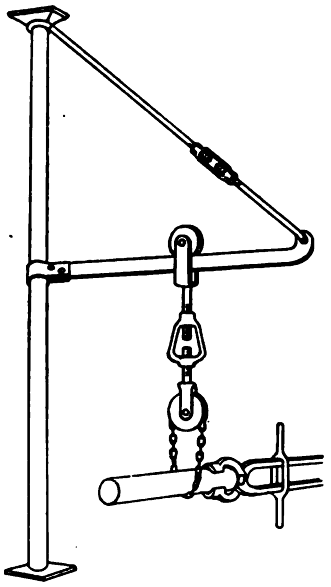

Fig. 166.

Flanging Press. A particular type of forging press is the flanging press. This is used more particularly in boiler work and is generally a heavy hydraulic press. The flanging is done by placing the heated metal on the bed of the press and closing the dies together by hydraulic pressure.

Cranes. Where heavy work is to be handled, it is necessary to have some means of conveying the work from one part of the shop to another. This is done by means of cranes of two general types. The traveling crane and jib crane. The former type runs on an overhead track from one end of the shop to the other, generally. The latter type is used more commonly for handling work under the hammers, and is merely an arm or boom swinging around a post and having a suitable arrangement for raising and lowering the work. When handling heavy work, whenever possible, it is suspended from the crane by its center, in such a way that it nearly balances. The suspending is generally done by means of an endless chain such as illustrated in Fig. 166, and in this way it may be easily rolled and swung from side to side. For ease in handling large forgings, a bar, or handle is sometimes welded on. This is known as a porter bar.

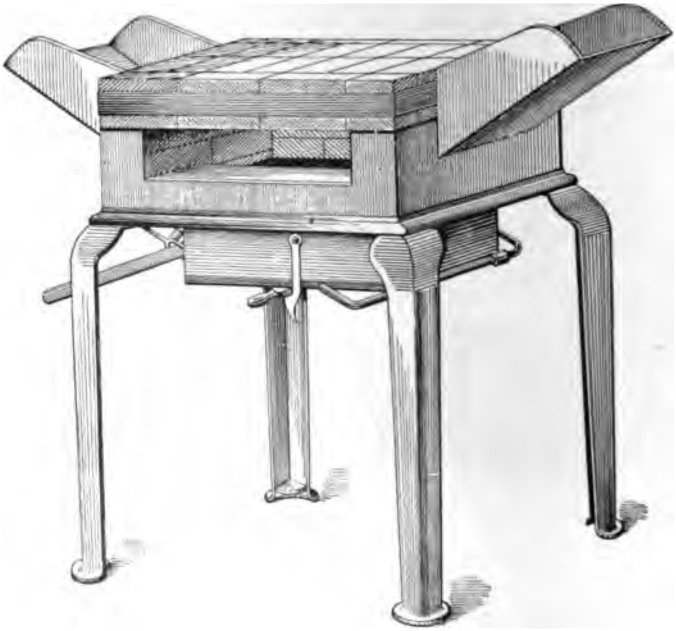

Fig. 167.

Furnaces. In nearly all manufacturing work and in large work in the jobbing shop, the heating is done in furnaces. The heat is generally supplied by either hard coal, coke or oil, coke being more commonly employed in jobbing shops. Sometimes ordinary coal is used. A furnace used for heating small work for manufacturing is shown in Fig. 167. This may be used with either ordinary coal or coke.

Gas Furnaces are used when an even heat is wanted, particularly for hardening and tempering. For manufacturing work the furnaces are sometimes fixed to do the heating automatically. The pieces to be hardened are carried through the furnace on an endless chain which moves at a speed so timed that the pieces have just time enough to be heated to the right temperature as they pass through the furnace. Such a furnace is shown in Fig. 168. A simple gas furnace for all around work is shown in Fig. 169.

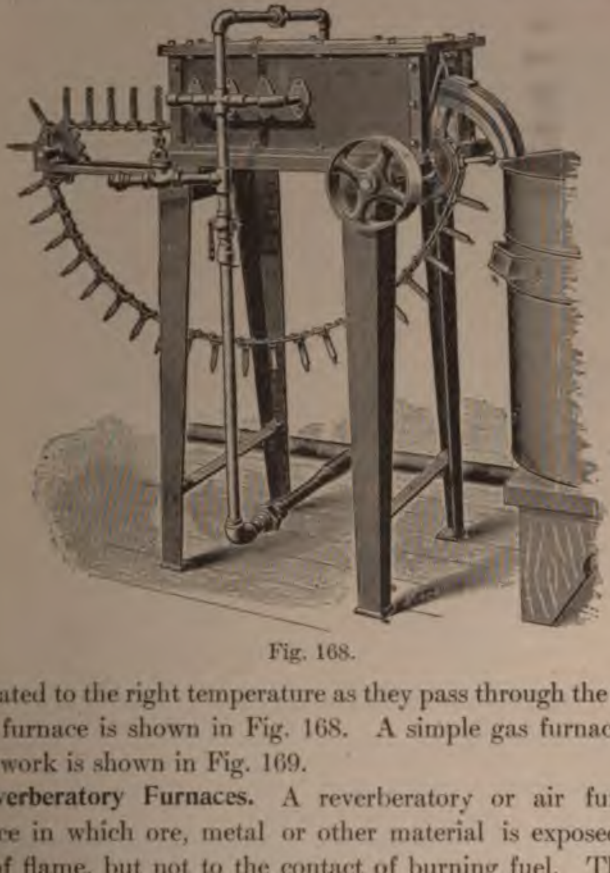
Fig. 168.

Reverberatory Furnaces. A reverberatory or air furnace is a furnace in which ore, metal or other material is exposed to the action of flame, but not to the contact of burning fuel. The flame passes over a bridge and then downward upon the material spread upon the hearth. Such furnaces are extensively used in shops where heavy work is being executed. They are also used for melting iron or other metals. For this purpose, however, they are not economical since they require about twice as much fuel as that used in the cupola for the production of good hot iron. To be effective the flame must be made to *reverberate* from the low roof of the furnace down upon the hearth and work. The form of the roof and the velocity of the currents determines the hottest part of the furnace.

A common form of reverberatory furnace is shown in Fig. 170. The whole is lined with fire brick from the top of the grates to the top of the stack. The fuel is burned in a fire box separated from the heating portion of the furnace by a low bridge wall D. Access to the grate is obtained by suitable doors both above and below. When in service, both doors are tightly closed and a strong forced draft is admitted to the ash pit. Beyond the bridge wall is the furnace proper. This usually consists of a low chamber with a level floor. Like the fire box it is completely lined with a thick wall of fire brick. Access is obtained to this chamber through a vertically sliding door. These doors are also lined with fire brick and are usually suspended from chains. These pass over pulleys, and have counter balancing weights at the other end.

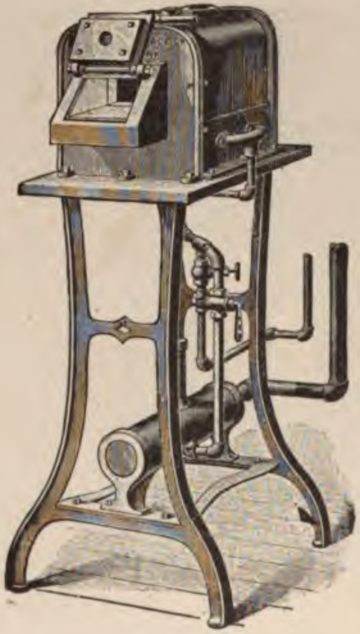
Fig. 169.

The operation of the furnace is exceedingly simple. After the fuel has been charged upon the grates, the ash pit and furnace doors are closed; the material to be heated is put upon the floor of the chamber; the doors are closed and the draft admitted to the ash pit. The thick walls which surround the furnace prevent radiation of its heat. The fire brick are, therefore, heated to incandescence and the hot gases sweep through the chamber. The flow of the gases is usually checked by a choke damper on top of the stack.

The outer form of these furnaces is usually rectangular. The brick walls are tied together by stay rods to prevent bulging and the corners are protected by angle irons.

The selection of the fuel is an important matter in the operation of these furnaces. Experiments have been made with almost every kind of fuel. That now universally used is a soft bituminous coal that will not cake.

Steam or power hammers are always used in connection with these furnaces. The work is too large and heavy for manipulation by hand hammers.

An ordinary class of work done with them is the welding of slabs from small pieces of scrap. To do this a rough pine board about 12 inches wide and from 15 to 18 inches long is used. On it is neatly piled about 200 pounds of small scrap pieces. This material is then bound to the boards by wires, and the whole is placed upon the hearth of the furnace. It is allowed to remain until the whole mass is at a welding heat. When in this condition, the plastic surfaces of the pieces serve to stick them together, so that the whole mass can be handled as a single unit by the tongs. The board, of course, burns away, leaving the metal on the hearth. The metal is then lifted out and placed under the steam hammer. A few light blows serve to do the welding. After this heavier blows are struck and the mass is hammered into any shape that may be desired. Usually this first hammering gives it the form of a slab. Slabs thus made are cut up and again welded to form the metal for the final shape.

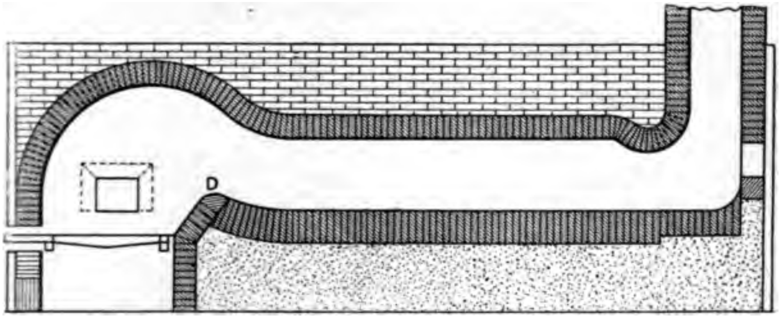

Fig. 170.

In the piling of the metal upon the board or *shingle*, as it is called, great care should be exercised. Iron and steel should not be piled together. Rusty metal should be cleaned before being put in the pile. Large air spaces between the pieces should be avoided.

The whole mass should be packed together as compactly as possible.

Bolt Headers are really upsetting machines that form the heads of bolts upon straight rods. Owing to the rapidity with which they do their work, they are invariably used for manufacturing bolts in quantities.

Miscellaneous Suggestions. In doing work in the blacksmith shop it must be constantly remembered that the work is larger at the time it is being manipulated than it will be when cool. Allowance must, therefore, always be made for shrinkage. As the pattern maker allows for the contraction of the molten metal to the cold casting, so the blacksmith must allow for the contraction of the hot iron or steel to the cold forging.

The temperatures of iron at the several colors, are as follows:

Lowest red visible in dark	878° F.
Lowest red visible in daylight	887° F.
Dull red	1100° F.
Full red	1370° F.
Light red, scaling heat	1550° F.
Orange	1650° F.
Light orange	1725° F.
Yellow	1825° F.
Light yellow	1950° F.

This table is based on temperatures given by Messrs. Taylor and White, Transactions Am. Soc. of Mech. Engs., Vol. XXI.

From the above it will be seen that the temperature at which forgings are finished under the hammer, should be at about 900° Fahr. When these same forgings are cold their temperature will be from 60° to 70° Fahr. There is, therefore, a difference of at least 840° between the working and the finished temperature. The expansion of iron may be taken to average about .00000662 of its length for each increase of one degree Fahrenheit in its temperature. If a bar of machine steel exactly 2 feet long when cold, be heated red hot and measured, it will be found to have increased nearly ¼″ in length. Taking the temperature of the red heat as 1370° F., and that of the cold bar as 70 F., the increase in length would be 1300 × .00000662 × 24 (length in inches) = .206″. This expansion must be allowed for when measuring forgings red hot.

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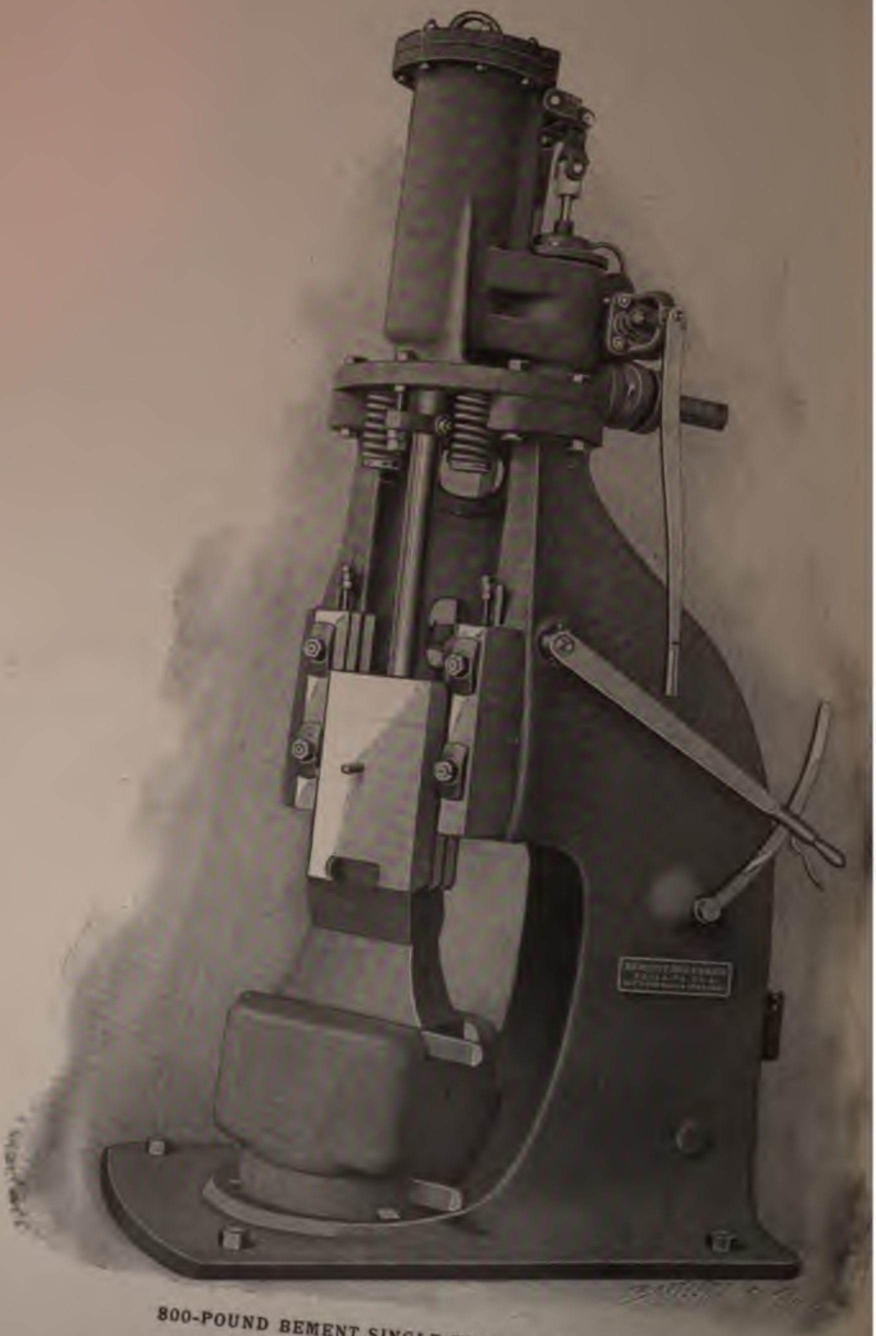


800-POUND BEMENT SINGLE-FRAME STEAM HAMMER.
Niles-Bement-Pond Company.

ELECTRIC WELDING DEVELOPMENT.

The art of welding iron is probably as old as the earliest production of that metal by man; in fact, the reduction of iron in the primitive forges demanded the union by welding of the reduced particles, for no true fusion could have resulted, the percentage of carbon present being too low. Until the closing years of the last century iron was the only weldable metal, if we except gold and platinum, -too expensive for common application.

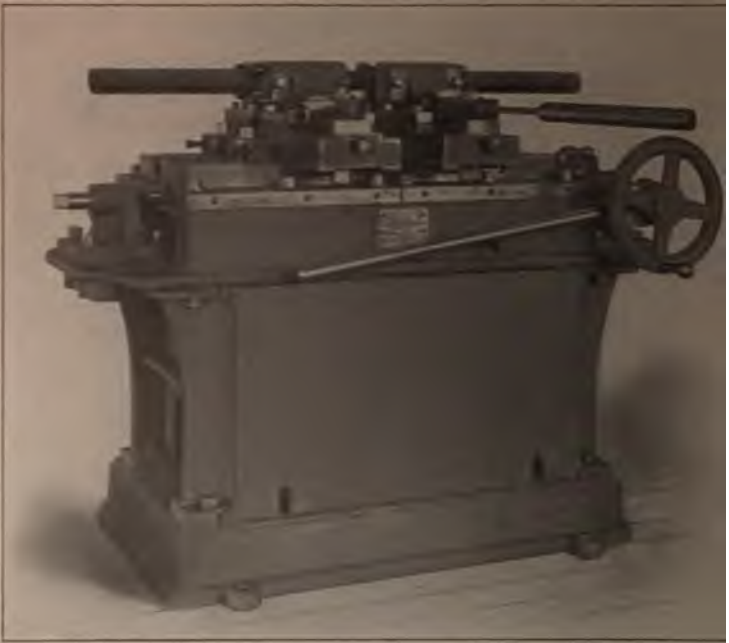
The fact that nearly pure iron, so difficult to melt, becomes quite plastic at high temperatures, while the oxide or black scale melts long before the metal itself becomes fluid, thus providing a liquid flux which is squeezed out during the process of union, accounts for the unique position which iron held until recent years. When, however, the heating effects of electric current energy, so perfectly under control, were applied to weld metals, a metal or alloy which would not weld became the exception, instead of the rule, as before. Much of the former work of the smithy fire is now accomplished by the electric welding transformer, and although many metals are easily manipulated by the electric process, iron, of course, still occupies, as ever, the principal place.

The electric weld is becoming a more and more important factor in many industries. During recent years the extension of its application has been steady, and each year has witnessed its entrance into new fields. Sometimes, indeed, new manufactures, or new ways of obtaining results have been based upon its use. The electric welds under consideration are the results of that operation of uniting two pieces of metal by what is known as the Thomson process, first brought out by the writer and rendered available in commercial practice a considerable number of years ago. The rapidity, flexibility, cleanliness, neatness, accuracy, and economy of the electric process has won for it such an important standing in the arts that many future extensions in its application are assured.

NOTE: This article by Prof. Elihu Thomson, the inventor of the system of Electric Welding, first appeared in Cassiers' Magazine, and is here reprinted by special permission.

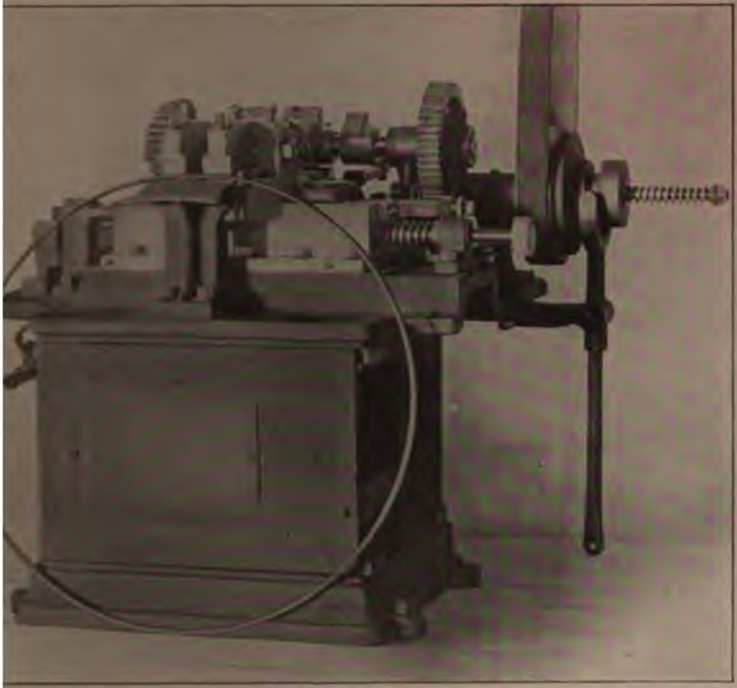
The uniformity of the work, the control of the operatio extreme localisation of the heat to the particular parts united, and the fact that the process is not limited to iro steel, but can deal equally well with other metals, such as c brass, bronzes, and even lead, are characteristics of the el welding operation.

The Electric Welder. In its simplest form, an el welder consists of a special transformer, the primary circ



ELECTRIC WELDING MACHINE FOR IRON AND STEEL PIPE.

which receives current from an electric station or dynamo g ator, at a voltage usually from one hundred to five hu times that required to make a weld. The copper secondary c of the transformer is generally only a single turn of very section, so that it may develop an extremely heavy current at two to four volts,—an electric pressure so low that it cannot the least effect of shock, and one for which there is no diffi in securing perfect insulation. The work pieces are hel clamps or vises, attached to or carried upon the terminals o



ELECTRIC TIRE-WELDING MACHINE.

e-turn secondary circuit. The control of the clamping devices
the current switch is either manual, or, in some cases, entirely
natic. Without attempting to enumerate the many applica-
of electric welding in the arts, we may refer to a few
ples.

Applications. In the waggon and carriage industry the proc-
s applied in the production of tires of all sections, axles, hub,
e and sand bands, fifth wheels, shifting rails, steps, shaft iron,
while it has found a large use in the welding into continuous
s or bands of the wires inclosed in rubber tires for holding
in place. The larger part of the dash-frames used in car-
s in the United States are now probably made by electric
ing, while iron and steel agricultural wheels are built up, or
their parts united, by electric welds.

To enumerate the many applications to the bicycle industry
d be almost to catalogue most of the metal parts of this use-

ful machine. It must be borne in mind, too, that a welding machine, slightly modified, is equally applicable for locally heating parts in electric brazing or hard soldering, for upsetting, and for bending or shaping. Bicycle crank hangers, pedals, seat-posts, fork and fork ends, frames and brake parts thus become products in which the welding transformer has its part. It has found a useful field also in tool manufacture, such as drills, reamers, taps, band and circular saws, drawing knives, carpenter's squares, printer's chases, etc., etc., and electric welding has a closely related use in the production of machine parts. Cam shafts and crankshafts are made from drop forgings welded together, teeth are inserted into gear wheels, and teeth are welded to saw bodies, including stone saws. Such things as inking rolls in printing machines and fallers for looms are additional examples.

In the wire industry the part played by electric welding is already quite important, and becomes steadily more so. Besides the mere simple joining of wires of iron, steel or copper into long lengths, the welding of wire or strip into hoops for barrels, tubs, pails, etc., is supplanting the older forms. Numerous machines are in operation turning out electrically-welded wire fence, much as a loom turns out cloth. In pipe bending and coiling, as in uniting ordinary lengths of pipe into very long lengths without screw joints, the electric weld has a special adaptability. Hundreds of miles of street railway rails have been welded into continuous lengths and now exist in many cities. Where rails are bonded only, the electric welder assists in the production of brazed or welded bonds.

It is a wide range between buckles, typewriter bars and umbrella rods to the local annealing of armour plates on warships, but the electric welder covers that range. It is no wider, however, than that from fine wires of a diameter of one-fiftieth of an inch up to heavy steel wire for the armour of submarine cables, and again up to street railway rail joints.

In recent years, elaborate machinery, for the actual production on a large scale of steel tubing from flat stock or skelp by the progressive welding of a longitudinal seam, has been put into operation. The long strip, or skelp, is rolled up so that its edges meet. In this condition it enters between the welding rolls, which

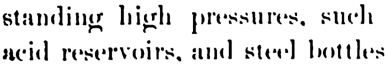
WELDING MACHINE FOR LARGE TUBES OR SHELLS UP TO 16 INCHES IN DIAMETER.

pass the heating current locally across the edges to weld them, and the operation is progressive from one end of the pipe to the other as it is fed into the machine. The result is a pipe of which the walls are of even thickness and the diameter uniform. This pipe can be afterward drawn, if needed, to the exact size desired. Very thin pipe can be made of steel, the longitudinal seam or weld in which is a delicate bead along the length,—a beautiful product, for the extreme localisation of the heat has allowed preservation of surface and finish of the metal outside the joint. Taper tubes, such as are used for bicycle front forks and the like, are easily made.

A similar machine for large work has lately been constructed, and by its use large diameter tubes or shells, up to 16 inches in diameter, are produced from sheet steel or iron. The accompanying illustration shows such a machine ready for operation. The welding transformer is at the top of the machine, and the secondary circuit has for its terminals two copper rolls inclined to each other on two nearly horizontal shafts adjustable in position over the work. Below are the guide rolls, one on each side on vertical shafts, and between these the shell to be welded passes with its meeting edges uppermost and in contact with the copper contact rolls. As the metal shell passes along under these rolls the joint is progressively heated by the welding current crossing it, and the weld is finished by the side pressure of the guiding rolls. The process, as well as the resulting welded product, is unique.

For a considerable time past, welding machines have been applied to the production of bands or tires from stock of varying width, thickness, and sectional form. More recently the practice of welding plain bands or cylindrical rings, and afterwards rolling them with the form of section desired, has been largely adopted: such as, for example, in the production of automobile wheel rims, bands for roving cans, stove rings, etc.

Very different from this is the formation of crankshafts, now demanded in great numbers for engines of automobiles. These are made from drop forgings and round shaft stock by uniting the pieces, as in the annexed sketch, and afterwards lightly machining and finishing the approximately correct shaft, as produced by welding.



Besides the banding of wire or strip of such comparatively frail containing vessels as barrels or pails, the electric weld finds application in the forming and capping of metal vessels for withstanding high pressures, such as soda-water cylinders, carbonic acid reservoirs, and steel bottles for nitrous oxide gas.

One of the most interesting of the more recent applications is that of welding hollow steel handles on cutlery, such as table

ELECTRIC RAIL WELDING ON STREET RAILWAYS.

knives and forks. The operation is remarkable for the celerity and neatness of the work, the articles being finished by silver-plating and polishing, as usual. The hollow handle is drawn from thin steel, and united to the knife blade or to the fork, as the case may be, in a special welding machine, there being no brazing or other operation of joint-forming required. There is, indeed, no limit to the delicacy of the work which may be undertaken, provided only the welding apparatus is equally refined.

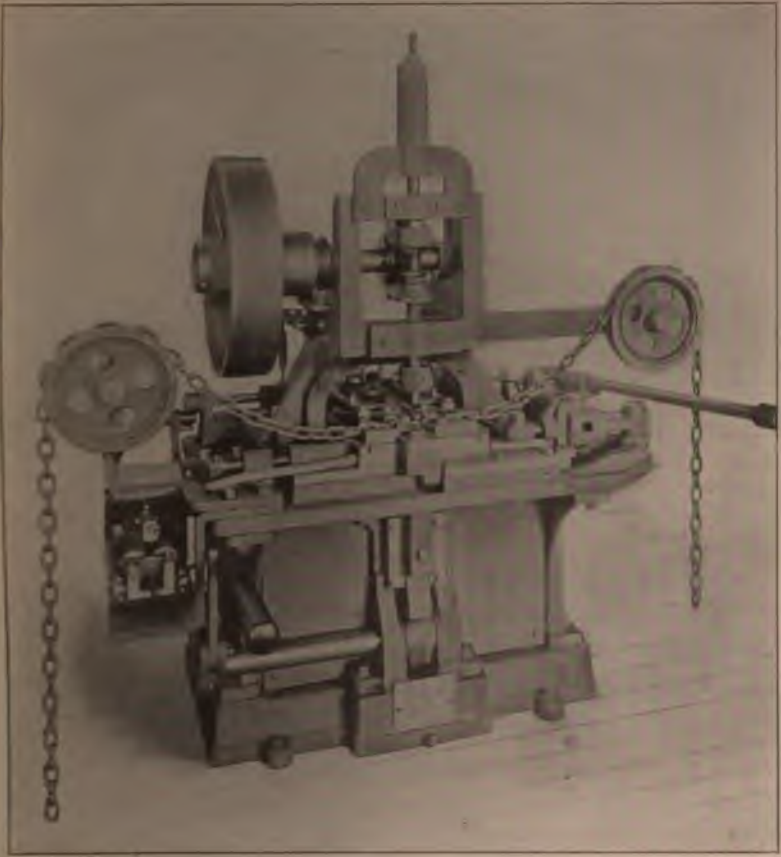
Adjustments. In the simpler types of electric welders, especially where the machine is designed to do a variety of work, perhaps of different forms or sizes of pieces, or both, the adjustments are usually manual; that is to say, the operations of clamping the pieces and applying the electric current and mechanical pressure are each controlled by the operator. In other cases, such as in the welding of copper or aluminium wire, the machine is, at least in part, automatic. The pressure is automatically applied and the welding current is cut off automatically upon the completion of the joint; the placing of the pieces in the clamps and the switching on of the current is in this case, manually performed.

In other, more completely automatic, types, particularly adapted for rapid repetition of the same operation on identical pieces, the machine runs continuously, and its sequence of actions is definitely determined by the construction. In such cases a source of power, as by a belt, drives the machine, the movement so imparted having the effect of clamping the pieces as they are fed to the machine, putting on the current, applying the pressure, cutting off the current and releasing the pieces.

The mechanism which has been developed for these purposes displays, in many instances, much ingenuity. In these machines the duty of the attendant is limited to the mere placing of the pieces between the clamping jaws, just before they are clamped, and the work is characterised by rapidity and by uniformity of the results.

More completely automatic still are machines for the production of wire fencing and for the consecutive welding of the links of chains. In these the operation, once started, goes on uninterruptedly so long as the work holds out, or until the stock undergoing operation is exhausted. In the fence machines, of which fifteen are now in existence, galvanised iron wires are fed from reels parallel to one another, at distances apart depending on the mesh desired. These may correspond to the warp in weaving. Transversely to these, and at intervals corresponding to the mesh selected, are fed wires, cut from a reel, which transverse wires are the verticals in the finished fence itself and correspond to the weft in weaving. A series of small welders are automatically brought into operation to weld each transverse wire to the longitudinals where the two cross. This done, the web so formed moves forward, the operation repeats itself, and so on continuously. The welding is, in this case, practically instantaneous, and all of the movements of the machine are entirely automatic.

In this way it is possible for a single machine to turn out many thousands of feet of fencing per day with a width of mesh from 2 or 3 inches up. Less wire is used than where the joints are made by twists or loops, and the stability or fixedness of position of such joints as are made is much more assured.



ELECTRIC CHAIN-WELDING MACHINE.

Joints. While in most cases of electric welding the joint forms what is known as a butt weld, with a burr or extension of metal at the joint, which, according to conditions, is either allowed to remain or is forged down or dressed off, there is no difficulty in making lap welds electrically, and some of the recent work of the electric welder is of that character. While, too, the usual welding concerns pieces of the same metal, as iron to iron, steel to steel, or copper to copper, combination welds of different metals are made with facility in many cases, as when brass and iron are united.

In the working of high-carbon steels the usual precautions to prevent burning or injury to the metal are, of course, required; but, on account of the delicacy of heat control, they are more easily adopted.

ROLLS OF ELECTRICALLY-WELDED WIRE FENCE.

Quite recently automatic chain welders have been put into use, and electrically-welded chain work will probably soon attain an importance not second to the other principal applications which have been briefly described.

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band iron, square or round rods for bracing, etc., zinc, copper, or brass; and the weight of the metal must often be calculated together with that of stiffening rods, braces, etc. On this account it is necessary to have tables which can be consulted for the various weights.

TABLES.

There is a wide difference between gauges in use, which is very annoying to those who use sheet metal rolled by different firms according to the various gauges adopted. It would be well to do away with gauge numbers, and use the micrometer caliper shown in Fig. 1, which determines the thickness of the metal by the decimal or fractional parts of an inch.

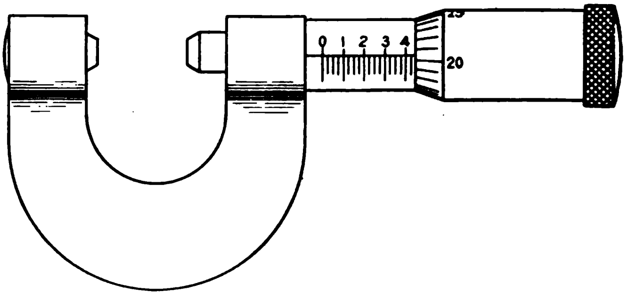


Fig. 1.

This is the most satisfactory method for the average mechanic who works sheet metal manufactured by firms using different gauges. The tables on pages 61 to 74 can be consulted when occasion arises.

SHOP TOOLS.

In allowing edges for seaming and wiring, we must bear in mind that when a seam is to be grooved by hand or machine the allowance to be made to the pattern should conform to the rolls in the machine or the hand tools in use. The edges of the pattern are usually bent on the sheet-iron folder, or brake, while the seam can be seamed or grooved with the hand groover or giant grooving machine. Where round pipe work is done in lengths up to 3 feet, the slip roll former is used, while square or rectangular pipes are bent up on the brake in 8-foot lengths. Where pipes, elbows,

SHEET-METAL WORK.

PART I.

The sheet-metal worker of today who wishes to succeed must know far more than was necessary years ago. There are many good, practical sheet-metal workers in the trade who are handicapped because they are unable to lay out the patterns that arise in their daily work. Notwithstanding the introduction of labor-saving machinery, the demand for good workmen has increased. While most sheet-metal workers acquire practical knowledge in the shop, they lack the technical education necessary to enable them to become proficient as pattern cutters and draftsmen. In this course, special attention is given to the fundamental principles that underlie the art and science of pattern drafting.

Practical workshop problems will be presented, such as arise in everyday practice, thus giving the student the practical experience that usually comes only after long association with the trade.

CONSTRUCTION.

In constructing the various articles made from sheet metal, various gauges or thicknesses of metal are used. For all gauges from No. 20 to No. 30 inclusive, we assume in the development of the pattern, that we are dealing with no thickness, and we make no allowance for bending or rolling in the machine. But where the metal is of heavier gauge than No. 20, allowance must be made for shrinkage of the metal in the bending and rolling operations, which will be explained in connection with development in heavy sheet-metal work. What has been said about wiring, seaming, and transferring patterns in the Tinsmith's Course is applicable to this course also. It is sometimes the case that the capacity of a vessel or article must be determined, when the rules given in Mensuration should be followed. When figuring on sheet-metal work, the specifications sometimes call for various metals, such as galvanized sheet iron or steel, planished iron, heavy boiler plate, which draw horizontal lines intersecting the section F at *a′*, *a′*, *a′*, and *a′*. Take a tracing of the section F with its various intersections, and place it in its proper position as shown by F¹, in the

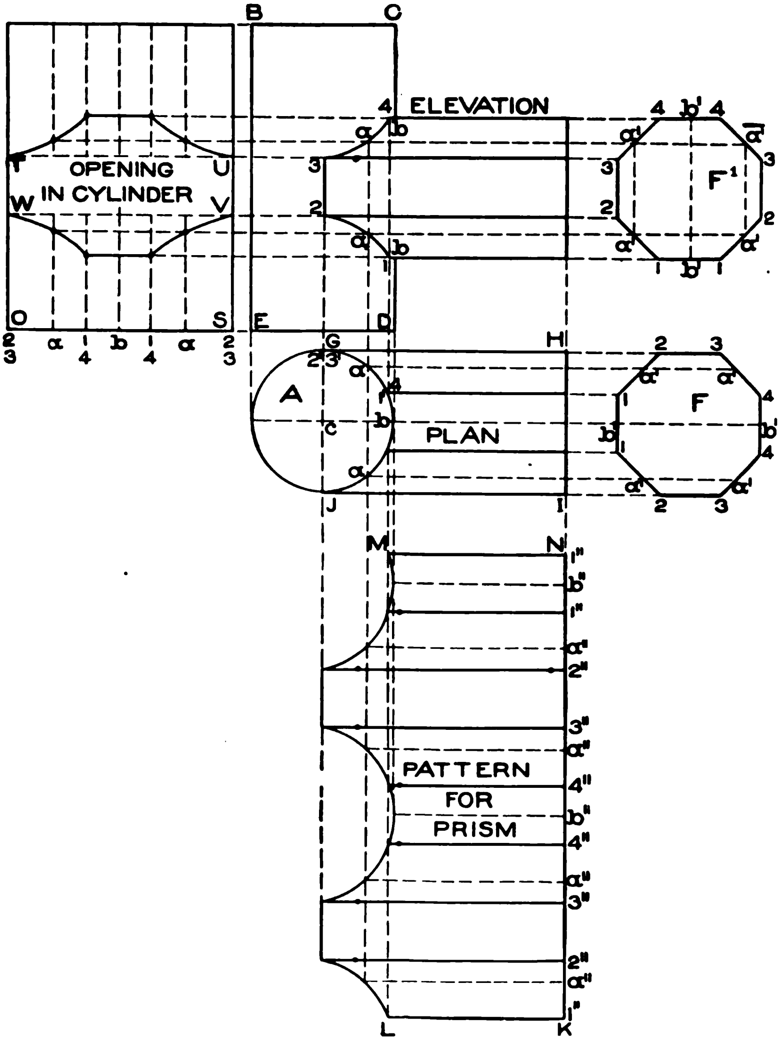


Fig. 2.

center of the cylinder B C D E, allowing the section to make a quarter turn, and bringing the points *b′ b′* at the top and bottom on a vertical line, while in the section F, *b′ b′* are on a horizontal line. From the various intersections in F^1, draw horizontal lines intersecting vertical lines drawn from similarly numbered intersections in the plan A, as shown in elevation. A line drawn through these points will represent the joint between the cylinder and prism.

For the development for the prism, extend the line H I in plan as N K, upon which place the stretchout of all the points contained in the section F, as shown by similar figures and letters on N K. Through these points, at right angles to N K, draw lines which intersect with lines drawn from similarly numbered points and letters in plan, at right angles to J I. Trace a line through points thus obtained, and K L M N will be the desired pattern. To obtain the development for the opening in the cylinder, extend the line D E in elevation as S O, upon which place the stretchout of all the points contained in the half-circle A, as shown by similar numbers and letters on S O. At right angles to S O and through these points, draw lines intersecting horizontal lines drawn from intersections having similar numbers and letters in elevation, thus obtaining the intersections shown by T U V W, which will be the shape of the opening to be cut into one-half of the cylinder.

In Fig. 3 is shown the intersection between a hexagonal and quadrangular prism, the hexagonal prism being placed in elevation at an angle of 45° to the base line. When drawing this problem for practice, make the height of the quadrangular prism 4½ inches, and each of its sides 2 inches. Place the hexagonal prism at an angle of 45° to the base line, placing it in the center of the quadrangular prism in elevation as shown; and inscribe the hexagonal section in a circle whose diameter is 2½ inches. Let A represent the plan of the quadrangular prism placed diagonally as shown, above which draw the elevation B C D E. In its proper position and proper angle, draw the outline of the hexagonal prism as shown by 1^v 1″ 4″ 4^v; and on 1″ 4″ draw the half section as shown by F, numbering the corners 1″ 2″ 3″ and 4″. From the corner 1′ in the plan A, draw the center line 1′ 4. Take a tracing of the half section F, and place it as shown by F^1, placing the points 1″ 4″ in F on the center line in F^1 as shown. From the corners 1, 2, 3, and 4, draw lines parallel to the center line, intersecting the two sides of A (*b* 1′ and 1′ *a*) at 2′ 3′ and 1′ 4′, as shown. From these intersections draw vertical lines, which intersect by lines drawn parallel to $4'' \, 4^{v}$ from corners having similar numbers in F, thus obtaining the points of intersection 1^{v} 2^{v} 3^{v} and 4^{v}. Dropping vertical lines from the intersections on the plane $1'' \, 4''$ in elevation, and intersecting similarly numbered lines in plan, will give the horizontal section of $1'' \, 4''$, as shown by 1° 2° 3° and 4°.

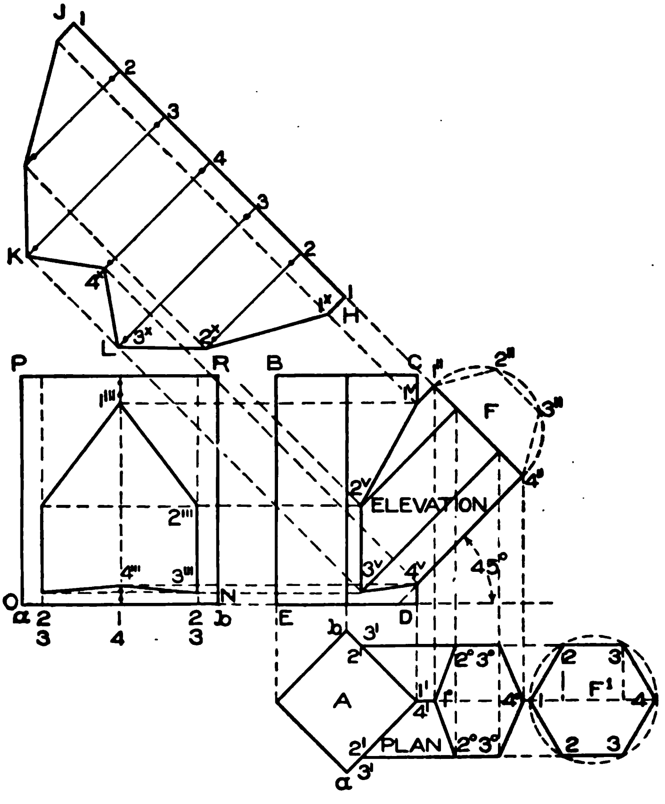


Fig. 3.

For the development of the hexagonal prism, extend the line $4'' \, 1''$ as shown by H J, upon which place the stretchout of twice the number of spaces contained in the half section F, as shown by similar figures on the stretchout line H J. From these points, at right angles to H J, draw lines as shown, which intersect by lines drawn at right angles to the line of the prism from intersections 1^{v} to 4^{v}, thus obtaining the points of intersection 1^{x} to 4^{x}. Lines traced from point to point as shown by J K L H, will be the required development. The shape of the opening to be cut into the quadrangular prism, is obtained by extending the line D E in elevation as N O, upon which place the stretchout of one-half the section A, with the various points of intersection, as shown by similar figures on O N. At right angles to O N erect lines from these points, which intersect by lines drawn from similarly numbered intersections in elevation at right angles to the quadrangular prism, thus obtaining the points of intersection $1'''$ to $4'''$ on both sides. Then N O P R will be the half development.

Fig. 4 shows the intersection between two cylinders of equal diameters at right angles. Make the height of the vertical cylinder 3 inches, that of the horizontal cylinder 1¼ inches, and the diameters of both 2 inches. Let A represent the plan of the vertical cylinder, and B its elevation. Draw the plan of the horizontal cylinder C, shown in elevation by D placed in the center of the vertical cylinder. Draw the half section E in plan and divide it into equal parts, as shown from 1 to 3 to 1. In a similar manner draw the half section E^1 in elevation, which also divide into the same number of spaces as E, reversing the numbers as shown.

The following suggestions are given to avoid confusion in numbering the points or corners of irregular or round sections in plan and elevation. If the half section E were bent on the line 1–1 and turned upward toward the reader, and we should view this section from the front, the point 3 would be at the top, or, if bent downward, would be at the bottom; therefore the points 3 and 3 in elevation are placed at top and bottom. Now if the section E^1 in elevation were bent on the line 3-3 either toward or away from the reader, the point 1 when looking down would show on both sides as shown in plan, which proves both operations. No matter whether the form is simple, as here shown, or complicated as that which will follow, the student should use his imaginative power. Study the problem well; close your eyes and imagine you see the finished article before you, or, failing in this, make a rough model in the shop or a cardboard model at home, which will be of service. Now from the intersections in E, draw horizontal lines intersecting the circle A at $1'$, $2'$ and $3'$ on both sides. From these points erect perpendicular lines and intersect them with horizontal lines drawn

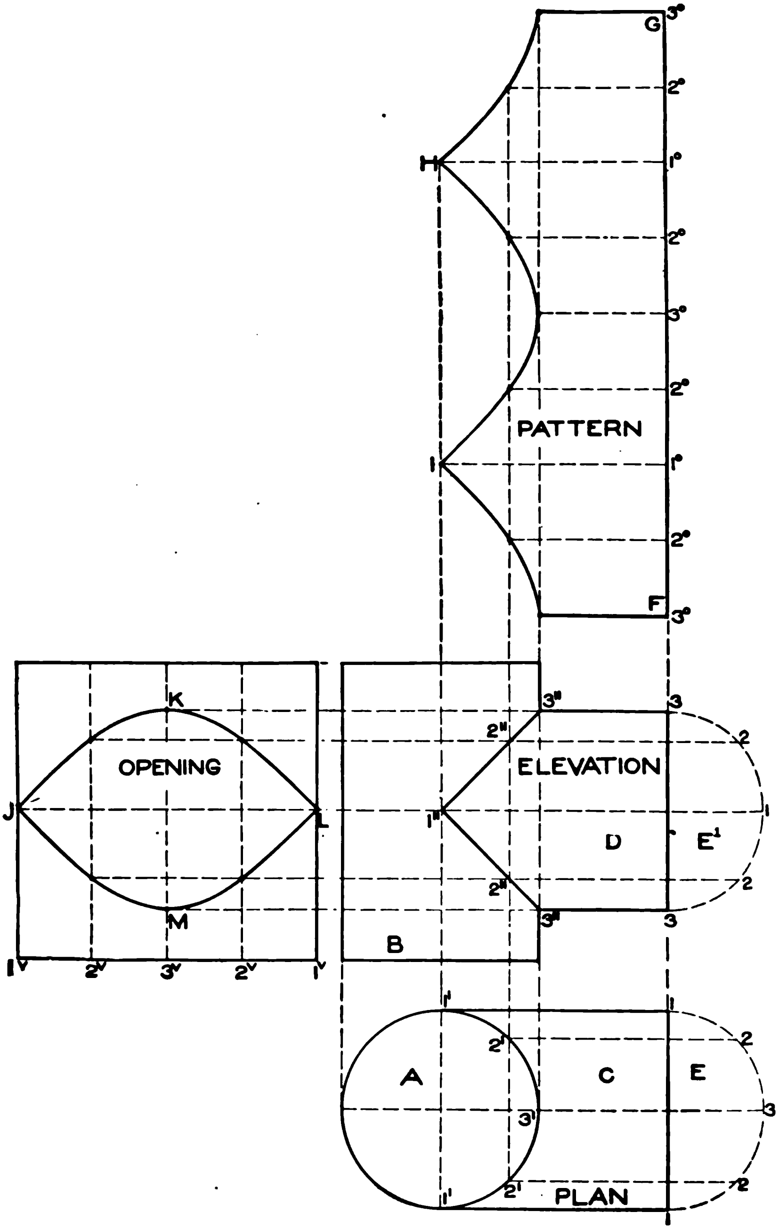

G
3°
2°
1°
H
I
PATTERN
F
K
OPENING
J
L
M
1ᵛ
2ᵛ
3ᵛ
2ᵛ
1ᵛ
3''
2''
1''
ELEVATION
D
E¹
B
3
2
1
1'
2'
3'
A
C
E
PLAN

Fig. 4.

from similarly numbered intersections in E^1. Lines traced through these points $3' \; 2' \; 1'$ and $1' \; 2' \; 3'$ will be straight because both branches are of equal diameters.

For the development of the cylinder D in elevation, extend the line 3-3 as shown by F G, upon which place the stretchout of twice the number of spaces contained in E^1, as shown by similar numbers 3° to 1° to 3° to 1^{c} to 3° on the stretchout line F G. From these points, at right angles to G F, draw lines, and intersect them by lines drawn parallel to the cylinder B from similar numbers in the joint line. Trace a line through these points in the development, when F G H I will be the desired shape.

For the opening to be cut into the cylinder B to receive the cylinder D, extend the base of the cylinder B as shown by $1^{v} \; 1^{v}$, upon which place the stretchout of the half circle A in plan, as shown by similar figures on the stretchout line $1^{v} \; 1^{v}$. From these points erect perpendiculars, which intersect by lines drawn from similarly numbered intersections in elevation at right angles to the line of the cylinder B. Trace a line through the intersections thus obtained; J K L M will be the shape of the opening.

Fig. 5 shows the intersection of two cylinders of unequal diameters at an angle of 45°. Make the diameters of the large and small cylinders 2 inches and 1¼ inches respectively; the height of the large cylinder 3 inches; and the length of the small cylinder measured from its shortest side in elevation, 1 inch, placed at an angle of 45° in the center of the cylinder B. A represents the plan of the large cylinder struck from the center *a* and shown in elevation by B. Draw the outline of the small cylinder C at its proper angle, and place the half section D in its position as shown; divide it into a number of equal spaces, as shown from points 1 to 5. Through the center *a* in plan, draw the horizontal line *a* 5; and with *b* as a center describe a duplicate of the half section D with the various points of intersection, as shown by D^1, placing the points 1 and 5 on the horizontal line *a* 5. From the intersections in D^1 draw horizontal lines intersecting the large circle A at $3'$ to $3'$ as shown, from which points erect perpendicular lines; intersect them by lines drawn parallel to the lines of the smaller pipe from similarly numbered intersections in D. A line traced through the points thus obtained will represent the intersection or miter joint between the two pipes.

These same principles are applicable no matter what diameters the pipes have, or at what angle they are joined, or whether the pipe is placed as shown in plan or at one side of the center line.

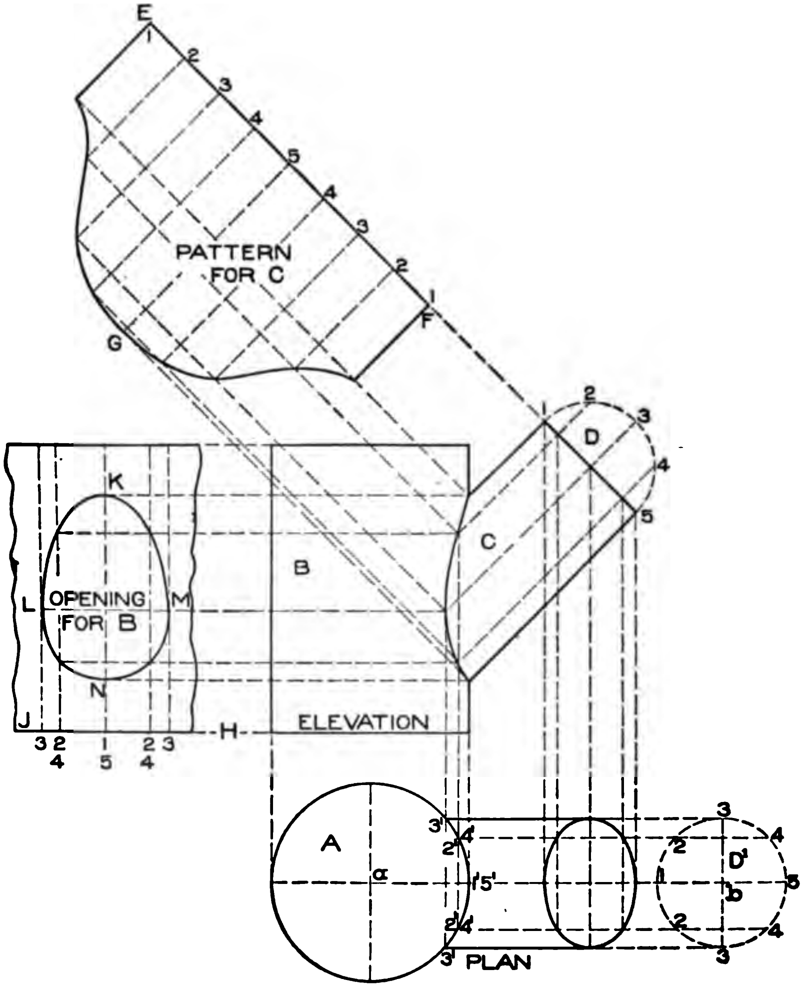


Fig. 5.

For the development of the small cylinder extend the line 5 – 1 in elevation as shown by F E, upon which place the stretchout of the circle D^1 in plan, or twice the amount of D in elevation, as shown by similar figures on the stretchout line F E. At right angles to F E and through these small figures, draw lines which intersect with lines drawn at right angles to the lines of the small cylinder from similarly numbered intersections in the miter line in elevation. Trace a line through the points thus obtained; E F G will be the development for the cylinder C.

To obtain the opening in the large cylinder extend the lines of the large cylinder in elevation as shown at the base by H J, upon which place the stretchout of the intersections contained in the circle A, being careful to transfer each space separately (as they are unequal) to the stretchout line H J. Through these points and at right angles to H J erect lines which intersect with horizontal lines drawn from similar points in the miter line in elevation A line traced through the points thus obtained, as shown by K L M N, will be the desired development.

Fig. 6 shows the intersection between a quadrangular prism and sphere, the center of the prism to come directly over the center of the sphere. Make the diameter of the sphere 2½ inches, the sides of the prism 1½ inches, and the height from *f* to *c'* 2⅝ inches. Draw the elevation of the sphere A which is struck from the center *a*, from which erect the perpendicular *a b*. With any point, as *c*, as a center and using the same radius as that used for A, describe the plan B. Through *c* draw the two diagonals at an angle of 45°, and draw the plan of the prism according to the measurements given. Now draw the elevation of the prism *f c'* and *f' c*, the sides of the prism intersecting the sphere at *c* and *c'*. From either of these points draw a horizontal line intersecting the center line *a b* at *d*. Then using *a* as a center and *a d* as the radius, describe the arc *e e'* intersecting the sides of the prism extended at *e* and *e'*; *f e e' f'*

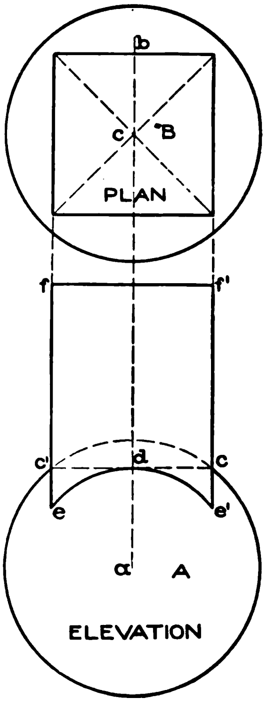


Fig. 6.

will be the development for one of the sides of the prism. In practice the four sides are joined in one.

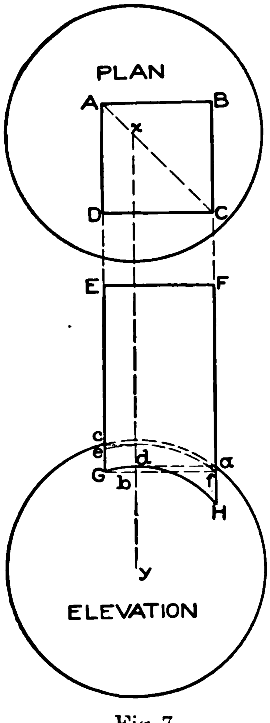


Fig. 7.

Fig. 7 shows the intersection of a quadrangular prism and sphere when the center of the prism is placed to one side of the center of the sphere. Make the diameter of the sphere the same as in the preceding figure; through x in the plan draw the 45° diagonal, and make the distance from x to A ½ inch, the sides of the prism 1 inch, and the height from E to c in elevation 1½ inches. Having drawn the elevation and plan of the sphere, construct the plan of the prism as shown by A B C D. Parallel to the center line x y project the prism in elevation intersecting the sphere at a and c. Now since the center of the sphere is on one of the diagonals of the prism in plan, either two of the sides meeting at one end of that diagonal, as B C and C D, will be alike, and both will be different from the other two sides A B and A D, meeting at the opposite end of the diagonal. Therefore the line F a in elevation will be used in obtaining the development of D C in plan, while the line E c will be used in obtaining the development for the two sides D A and A B in plan.

Now from a draw a horizontal line intersecting the center line x y at b; and using y as a center and y b as the radius, describe the arc G H intersecting the sides of the prism extended to G and H. Then E F G H is the development for each side of the prism shown in plan by D C and C B. In a similar manner, from the intersection c in elevation draw a horizontal line intersecting the center line x y at d. Then using y as center and y d as radius, describe an arc intersecting the sides of the prism at e and f. E F f e will show the development for either side of the prism shown in plan by D A and A B. By connecting the points G and f it will be found that the line is a true horizontal line, which proves the two developments. Should the plan of the prism be so placed on the sphere that all sides would be different, then two elevations would be necessary so that the intersections of all the sides could be shown.

Developments by Triangulation. In developing sheet-metal work of irregular forms, patterns are required which cannot be developed by either the parallel or radial-line methods. These irregular shapes are so formed that although straight lines can be drawn upon them the lines would not run parallel to one another, nor would they all incline to a common center. In the methods previously described, the lines in parallel developments run parallel to one another, while in radial-line developments all the lines meet at a common center. Hence in the development of any irregular article, it becomes necessary to drop all previous methods, and simply proceed to measure up the surface of the irregular form, part by part, and then add one to another until the entire surface is developed. To accomplish this, one of the simplest of all geometrical problems is made use of and shown in Part II of Mechanical Drawing, Plate V, Problem 11, entitled "To construct a triangle having given the three sides." To carry out this method it is necessary only to divide the surface of the plan or elevation of any irregular article into a number of equal parts. Use the distances in plan as the bases of the triangles, and the distances in elevation as the altitudes or heights of the triangles, or *vice versa;* and then find the hypothenuse by connecting the two given lengths.

To illustrate this simple principle Fig. 8 has been prepared. Let A B C D represent the plan of a plane surface, shown in elevation by A^1 B^1. We know that the true length of the plane is equal to A^1 B^1 and the true width is equal to A D or B C in plan. We also know that the vertical height from the bottom of the plane A^1 to the top B^1 is equal to B^1 b as shown. But suppose we want to obtain the true length of the diagonal line B D in plan on the developed plane. To obtain this it will be necessary only to take the length of B D, place it from b to D^1, and draw a line as shown from B^1 to D^1, which is the length desired.

While this may look very simple, it is all that there is to triangulation, and if the student thoroughly understands the simple principle and studies the problems which will follow, he will have no trouble in applying this principle in complicated work. T make it still clearer we will prove the length of the line B^1 D Take the distance of A^1 B^1, place it in plan as shown by A B^2, an complete the rectangle A B^2 C^2 D. Draw the diagonal B^2 D, bein the length sought, which will be found to equal B^1 D^1 in elevatio When drawing this problem in practice, make the plan 4 by 6 inche and the vertical height in elevation 5 inches.

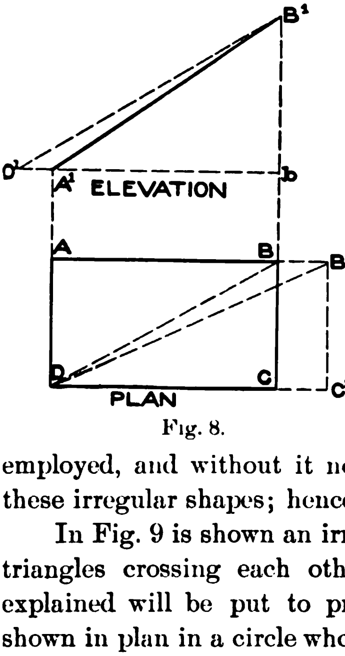


Fig. 8.

In obtaining developments by triangulation. the student shoul use all of his conceptive powers as previously explained. Befo making any drawing, he mu see the article before him in hi mind's eye, so to speak, befo he can put it down on pape Therefore we want to impres upon the student the necessity c drawing all the problems that wi follow in this part and in the Practical Workshop Problems.] should be understood that triangulation is not given as a alternative method, but is use when no other method can b employed, and without it no true pattern could be obtained fc these irregular shapes; hence the necessity of close study.

In Fig. 9 is shown an irregular solid whose base and top ar triangles crossing each other, and in which the principle jus explained will be put to practical test Inscribe the triangle shown in plan in a circle whose radius is equal to *a* 1, or 1½ inche and make the height of the article in elevation 2 inches. Th dotted triangles 1 2 3 in plan represent the section of the article o the line 2–3 in elevation: and the solid triangle 1^1 2^1 3^1 in plan, th section on the line 2^1 3^1 in elevation. Now connect the two section in plan by drawing lines from 1 to 2^1 and to 3^1, from 2 to 2^1 and t 1^1, and from 3 to 1^1 and to 3^1. In a similar manner connect th points in elevation as shown. It now becomes necessary to obtai a triangle giving the true length of the lines connecting th corners of the triangle in plan, and as all of these lines are equa only one triangle is necessary. Therefore take the distance fro

1 to 2^1 in plan and place it on the line 3–2 extended in elevation, as shown from 2 to 1°, and draw a line from 1° to 2^1, which is the desired length.

For the pattern, proceed as is shown in Fig. 10. Take the distance of any one of the sides in the triangle, as 1–2 in Fig. 9, and place it on the horizontal line 1–2 in Fig. 10. Then using 1 and 2 as centers, with 1° 2^1 in elevation in Fig. 9 as radius, describe the arcs in Fig. 10 intersecting each other in 2^1. Then 1 2 2^1 will be the pattern for one of the sides shown in plan in Fig. 9 by 1 2 2^1. Proceed in this manner in Fig. 10 as shown by the small arcs; or a tracing may be taken of the one side 1 2 2^1, and traced as shown until six sides are obtained, which will be the full pattern and which is numbered to correspond to the numbers in plan.

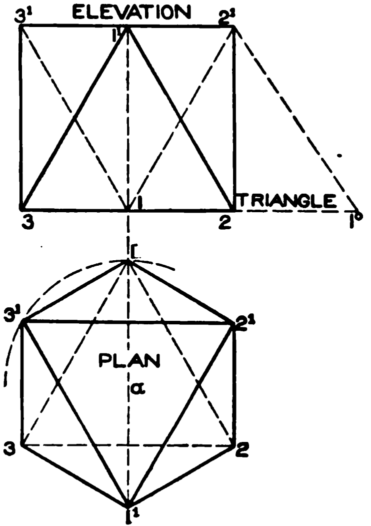


Fig. 9.

In Figs. 11, 12, and 13 are shown the methods used in developing a scalene cone. The method of obtaining the development of any scalene cone, even though its base is a perfect circle, is governed by the same principle as employed in the last problem on triangulation It is well to remember that any section of a scalene cone drawn parallel to its base will have the same shape (differing of course in size) as the base. This is equally true of articles whose

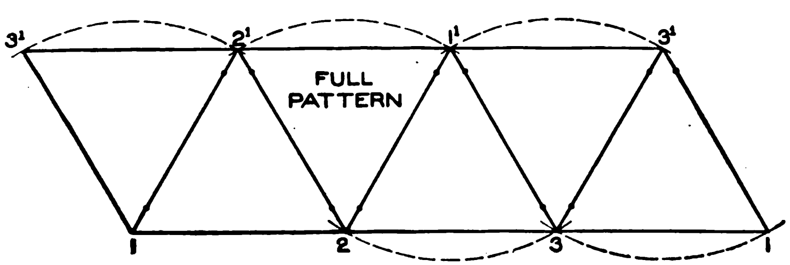


Fig. 10.

bases are in the shape of a square, rectangle, hexagon, octagon, or any other polygon. What has just been explained will be proven in connection with Fig. 11, in which A B C represents a side elevation of a scalene cone, whose plan is shown by 1 4^1 7 4 C^1. Draw any horizontal line, as A D, on which set off the distances A B equal to 3 inches and B D equal to 2½ inches, and the vertical height D C equal to 4½ inches. Draw lines from B and A to C, which completes the elevation. In its proper position below the line A B, draw the plan of A B as 1 4 7 4^1 struck from the center C. Through C draw the horizontal line C C^1, and

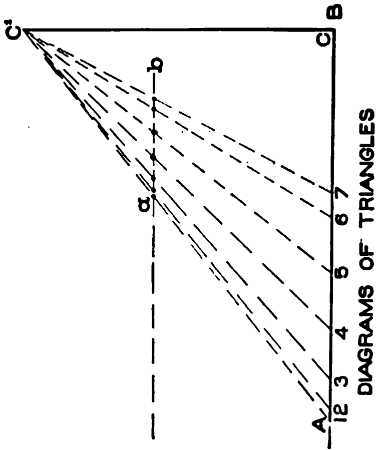


Fig. 12.

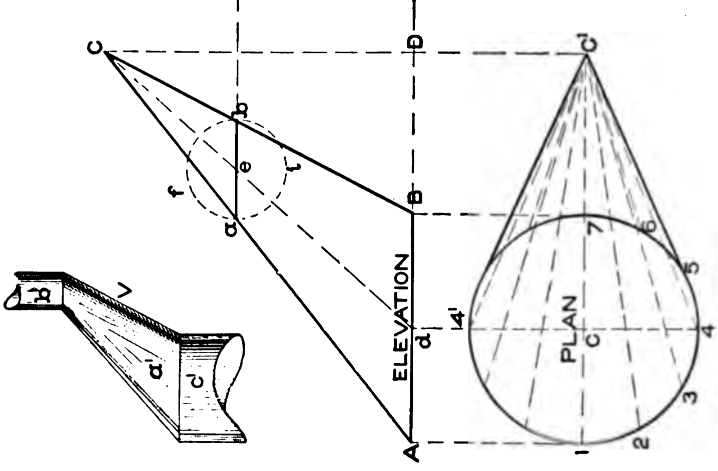


Fig. 11.

intersect it by a vertical line drawn from the apex C in elevation, thus obtaining the apex C^1 in plan. Draw lines from 4 and 4^1 to C^1, which completes the plan.

As both halves of the scalene cone are symmetrical, it is necessary only to divide the half plan 1 4 7 into a number of equal spaces as shown by the small figures 1 to 7, and from points thus obtained draw radial lines to the apex C^1. Then these lines in plan will represent the bases of triangles which will be constructed, whose altitudes are all equal to D C in elevation. Therefore in Fig. 12 draw any horizontal line, as A B, and from any point, as C, erect the perpendicular line C C^1 equal in height to D C in Fig. 11. Now from C^1 in plan take the various lengths of the lines 1 to 7 and place them on the line A B in Fig. 12, measuring in every instance from the point C, thus obtaining the intersections 1 to 7, from which lines are drawn to the apex C^1. Then these lines will represent the true lengths of similarly numbered lines in plan in Fig. 11.

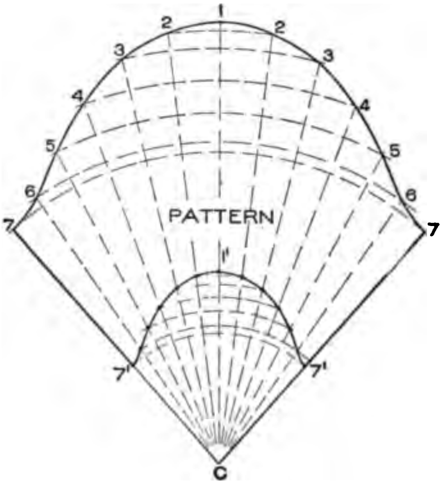


Fig. 13.

For the pattern proceed as is shown in Fig. 13. With C as center and radii equal to C^1 7, 6, 5, 4, etc., in Fig. 12, describe the arcs 7–7, 6–6, 5–5, 4–4, etc., in Fig. 13 as shown. Now assuming that the seam is to come on the short side of the cone, as C B in Fig. 11, set the dividers equal to one of the equal spaces in the plan; and starting on the arc 7–7 in Fig. 13, step from arc 7 to arc 6, to arcs 5, 4, 3, 2, and 1, and then continue to arcs 2, 3, etc., up to 7. Trace a line through these intersections as shown by 7–1–7, and draw lines from 7 and 7 to C, which completes the pattern.

Now to prove that any section of an oblique or scalene cone cut parallel to its base, has a similar shape to its base (differing in size), draw any line as *a b* in Fig. 11 parallel to A B. From C in plan erect a vertical line intersecting the base line A B at *d*, fro which draw a line to the apex C, cutting the line *a b* at *e*. Th the distances *e a* and *e b* will be equal; and using *e* as a center a *e b* as radius, describe the circle *a f b i*, which is the true secti

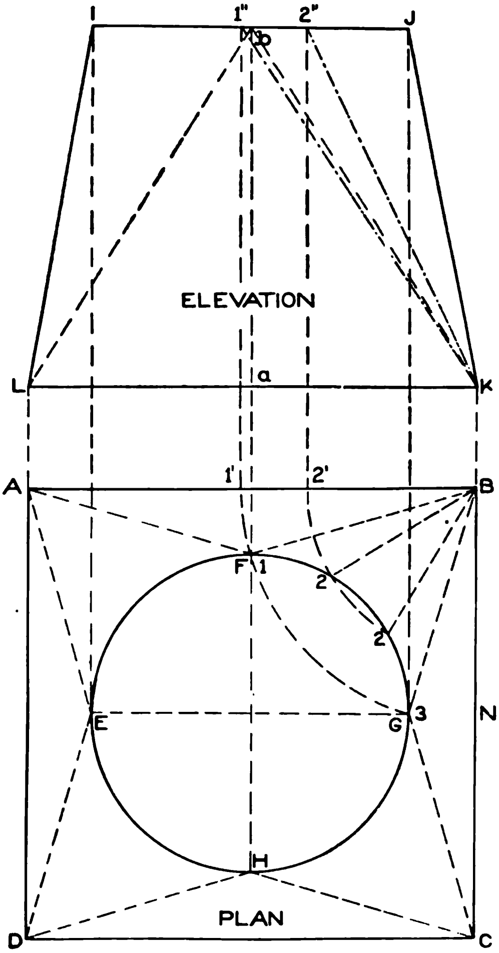


Fig. 14.

on *a b*. Then *a b* B will be the frustum a scalene cone. Exte the line *a b* parallel A D, cutting the diagra of triangles in Fig. from *a* to *b*. Then wi radii equal to the di tances from C^1 to t various intersections the line *a b*, and usi C in Fig. 13 as cent intersect similarly nu bered radial lines draw from 7 to 1 to 7 to t apex C. A line trac as shown from 7′ to to 7′ will be the desir cut, and 7-7-7′-7′ w be the pattern for t frustum. The practic use of this method shown in diagram V Fig. 11; *a′* is the fru tum of the oblique con on the ends of which a connected round pip *b′* and *c′*.

It is shown in Fig. 14 how in an irregular solid whose base square and top is round, both top and bottom on horizontal plan are developed. The corners in plan F B G, G C H, H D E ar E A F should be considered as sections of scalene cones. Proce by drawing the plan A B C D 3½ inches square, which represents t plan of the base of the article; and the circle E F G H 2½ inches in diameter, which shows the plan of the top of the article; the vertical height to be 3 inches, shown from *a* to *b*. As the circle is in the center of the square, making the four corners symmetrical, it is necessary only to divide the one-quarter circle into a number of equal parts as shown by the small figures 1, 2, 2, 3, from which draw lines to the apex B. Complete the elevation as shown by I J K L. Now using B as center, and radii equal to B 1 and B 2 in plan, describe arcs intersecting A B at 1′ and 2′ as shown. From these points erect perpendiculars intersecting the top of the article I J in elevation at 1′ and 2′, from which draw lines to K. Then K 1′ and K 2′ will be the true lengths of the lines shown in plan by B 1 and B 2 respectively on the finished article.

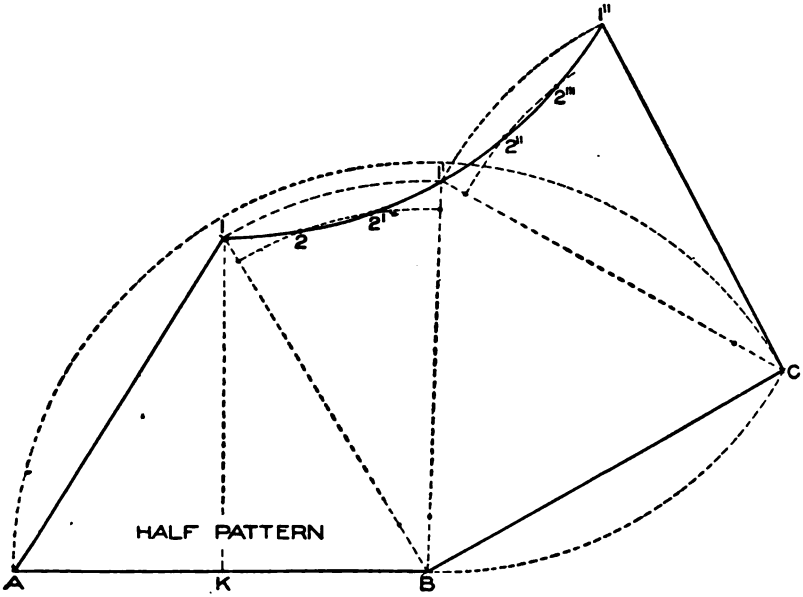


Fig. 15.

For the half pattern proceed as follows: In Fig. 15 draw any horizontal line, as A B, equal in length to A B in plan in Fig. 14. Now with K 1′ as radius and A and B in Fig. 15 as centers, describe arcs intersecting each other at 1 From 1 drop a vertical line intersecting A B at K. Then 1 K should equal J K in elevation in Fig. 14, which represents the true length through G N in plan.

Now with radii equal to K 1″ and K 2″ in elevation, and with B in Fig. 15 as center, describe the arcs 1–1′ and 2–2′. Now set the dividers equal to one of the spaces in G F in plan in Fig. 14; and starting at 1 in Fig. 15, step off arcs having similar numbers as shown by 1, 2, 2′, 1′. Now using 1 B as radius, and 1′ as center, describe the arc B C, and intersect it by an arc struck from B as center and with B A as radius, as shown at C. Take a tracing of 1 B 1′ and place it as shown by 1′ C 1″. Now connect the various intersections by drawing lines from 1 to A to B to C to 1″ to 1′ to 1, which completes the half pattern. The triangular pieces 1 A B or 1′ B C will represent the flat sides of the article shown in plan by 1 A B or 3 B C respectively in Fig. 14; and the cone patterns 1–1′ B and 1′–1″ C in Fig. 15, the sections of the scalene cones 1–3–B and H–G–C respectively in plan in Fig. 14. This same rule is applicable whether the top opening of the article is placed exactly in the center of the base or at one side or corner. Various problems of this nature will arise in Practical Workshop Problems; and if the principles of this last problem are thoroughly understood, these will be easily mastered.

Approximate Developments. In developing the blanks or patterns for sheet-metal work which requires that the metal be hammered or raised by hand, or passed between male and female dies in foot or power presses, circular rolls, or hammering machines, the blanks or patterns are developed by the approximate method, because no accurate pattern can be obtained. In all raised or pressed work in sheet metal, more depends upon the skill that the workman has with the hammer, than on the patterns, which are but approximate at their best. While this is true, it is equally true that if the workman understands the scientific rule for obtaining these approximate patterns a vast amount of time and labor can be saved in bringing the metal to its proper profile. If the true rule for averaging the various shapes and profiles in circular work is not understood, the result is that the blank has either too little or too great a flare and will not form to its proper profile and curve. Before proceeding to describe the approximate development methods, attention is called to the governing principle underlying all such operations. We have previously shown how the patterns are developed for simple flaring ware; in other words, how to develop the frustum of a cone. The patterns for curved or any other form of circular or hammered work are produced upon the same principle. The first illustration of that principle is shown in Fig. 16, in which A B C D represents a sphere 3 inches in diameter composed of six horizontal sections, struck from the center *a*.

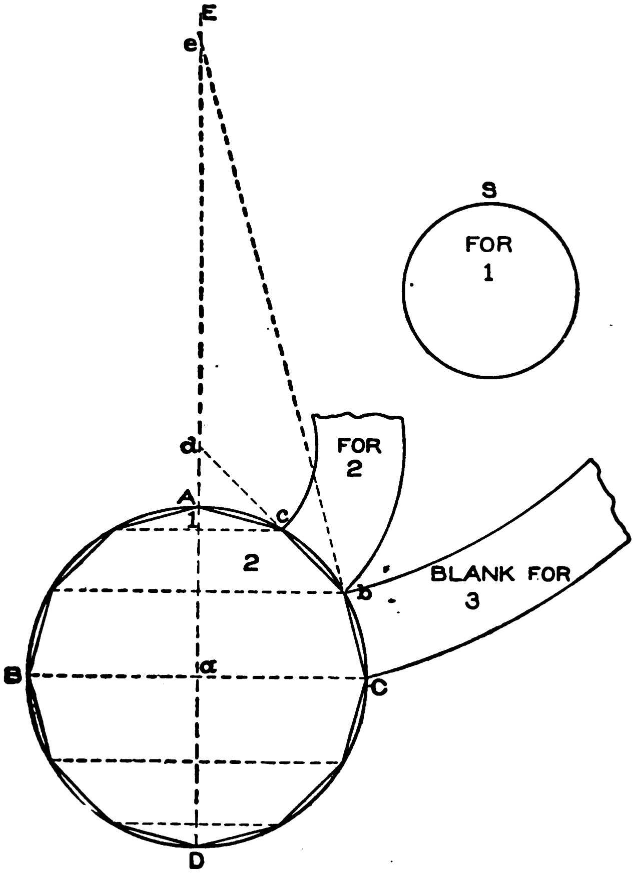


Fig. 16.

Divide the quarter circle A C into as many parts as there are sections required in the half sphere (in this case three), and draw horizontal lines through the ball as shown. The various radii for the patterns are then obtained by drawing lines through C *b*, *b c*, and *c* A. Thus C *b* extended meets the center line E D at *e*, which is the center for striking the blank for number 3, using the radii *e b* and *e* C. In similar manner draw a line from *b* to *c*, extending it until it meets E D at *d*. Then *d c* and *d b* will be the radii for blank number 2, while A *c* is the radius for blank 1 shown at S The lengths of the pattern pieces are determined in the same manner as would be the case with an ordinary flaring pan in producing the patterns for tin ware, and will be explained thoroughly in the Practical Workshop Problems which will shortly follow.

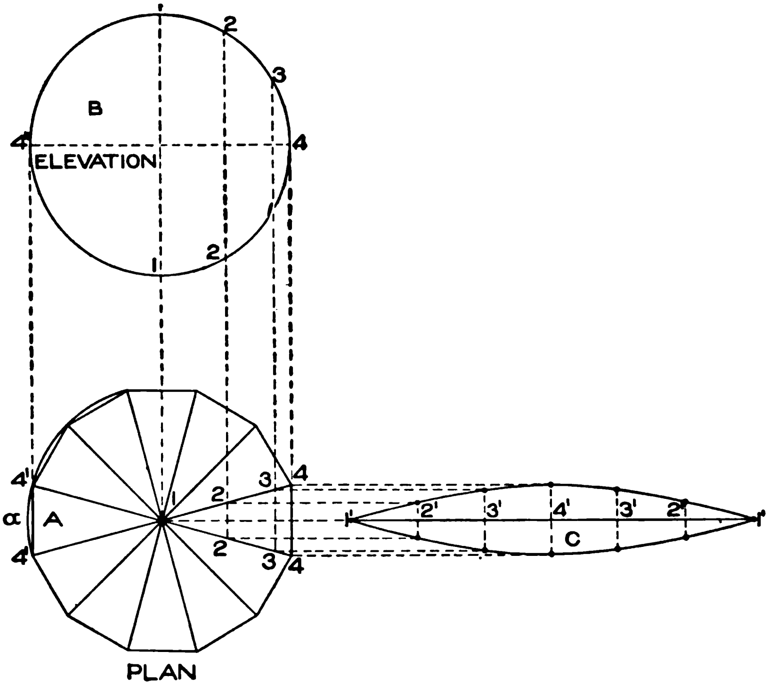


Fig. 17.

In Fig. 17 is shown another elevation of a sphere composed of twelve vertical sections as shown in plan view. While the method used for obtaining the pattern is by means of parallel lines, and would be strictly accurate if the sections in plan remained straight as from 4 to 4, the pattern becomes approximate as soon as we start to raise it by means of machine or hammer to conform to the profile B in elevation, because the distance along the curve *a* from 4′ to 4′

in plan is greater than a straight distance from 4 to 4. The pattern by this method is obtained as follows: Let B represent the elevation of the sphere, and A the plan of the same, which is divided into as many sides as the sphere is to have vertical sections, in this case 12, being careful that the two opposite sides 4–4 and 4′ 4′ in plan run parallel to the center line as shown. Make the diameter of the sphere 4–4″ 3 inches. Divide the half elevation into an equal number of spaces as shown from 1 to 4 to 1, and from these points drop lines at right angles to 4–4″ intersecting the miter lines 1–4 in plan as shown. Now draw any horizontal line, as 1′-1′, upon which place the stretchout of 1–4–1 in elevation as shown by 1′-4′-1′ on the line 1′-1′ in C. Through these points draw lines at right angles to 1′-1′, which intersect by lines drawn from similarly numbered intersections on the miter lines 1–4 in plan, at right angles to 4–4. A line traced through points thus obtained as shown by C will be the desired pattern.

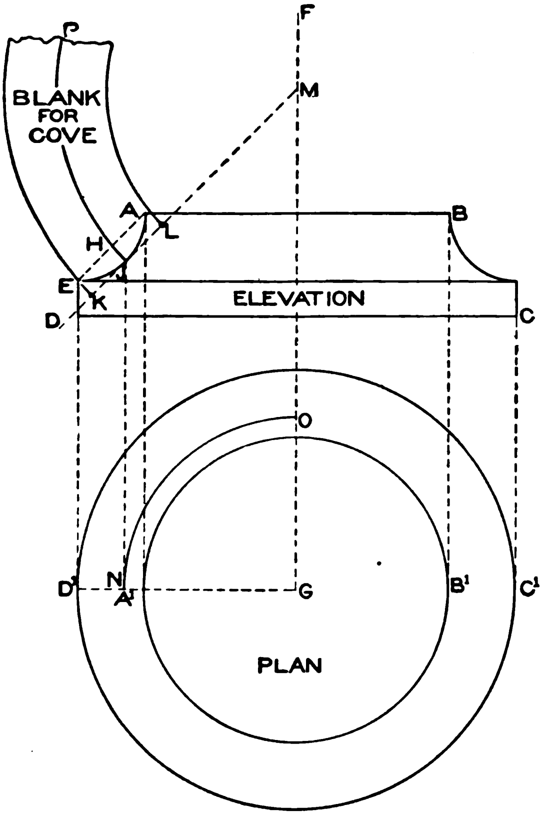


Fig. 18.

In Fig. 18 is shown the principle used in obtaining the radii with which to develop the blank for a curved or circular mould when it is to be hammered by hand. In this connection, only the principle employed will be shown, leaving the full development and also the development for patterns which are to be raised by hand

and hammered by machine, to be explained in problems which will follow in Practical Workshop Problems. Draw this problem double the size shown. First draw the elevation A B C D, and through the elevation draw the center line F G. Then using G as a center, draw the circles A^1 B^1 and C^1 D^1 representing respectively the horizontal projections of A B and C D in elevation. Now draw a line from A to E in elevation, connecting the corners of the cove as shown. Bisect A E and obtain the point H, from which at right angles to A E draw a line intersecting the cove at J. Through J parallel to A E draw a line intersecting the center line F G at M. Take the stretchout from J to A and from J to E and place it on the line J M as shown respectively from J to L and from J to K. Then will M L and M K be the radii with which to strike the pattern or blank for the cove. From J drop a vertical line intersecting the line D^1 G in plan at N. Then with G as center strike the quarter circle N O. Now using M as center and M J as radius, strike the arc J P. Then on this arc, starting from J, lay off 4 times the stretchout of N O in plan for the full pattern. It should be understood that when stretching the cove A E, the point J remains stationary and the metal from J to L and from J to K is hammered respectively toward J A and J E. For this reason is the stretchout obtained from the point J.

PRACTICAL WORKSHOP PROBLEMS.

In presenting the 32 problems which follow on sheet-metal work, practical problems have been selected such as would arise in every-day shop practice.

In this connection we wish to impress upon the student the necessity of working out each and every one of the 32 problems. Models should be made from stiff cardboard, or, if agreeable to the proprietor of the shop, the patterns can be developed at home, then cut out of scrap metal in the shop during lunch hour, and proven in this way.

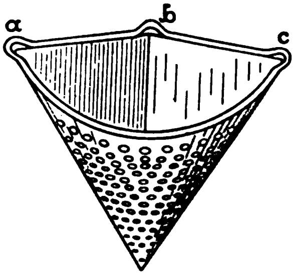


Fig. 19.

Our first problem is shown in Fig. 19, and is known as a sink drainer. It is often the case that the trap under the kitchen sink is choked or blocked, owing to a collection of refuse matter. To avoid this a sink drainer is used, and is fastened in position through the wire loops *a*, *b* and *c*. The refuse matter is poured into the drainer, from which it is easily removed after the fluid has passed through the perforations. These drainers may be made of tin or of black or galvanized iron, but where a good job is wanted 16-ounce copper should be used. To obtain the pattern for any sized drainer, proceed as follows: First draw the plan of the drainer A B C in Fig. 20, making A B and B C each two inches and forming a right angle. Then using B as center and A B as radius, draw the arc A C. In its proper position above the plan construct the side elevation, making E D 2 inches high, and draw the line F D. Then will F E D be the side elevation. Divide the arc A C into equal spaces as shown by the small figures 1 to 5. For the pattern use F D as radius, and with D in Fig. 21 as center strike the arc 1 5. From 1 draw a line to D and step off on 1–5 the same number of spaces as contained in A C in plan in Fig. 20, as shown by similar figures in Fig. 21. Draw a line from 5 to D. Then will 1–5–D be the pattern for the front of the strainer, in which perforations should be punched as shown. To join the sides of this pattern, use 1 and 5 as centers, and with either F E or A B in Fig. 20 as radius, describe the arcs E and E^1 in Fig. 21. Now using D as center and D E in Fig. 20 as radius, intersect the arcs E and E^1 as shown in Fig. 21. Draw lines from 1 to E^1 to D to E to 5, which completes the pattern, to which edges must be allowed for wiring at the top and seaming at the back.

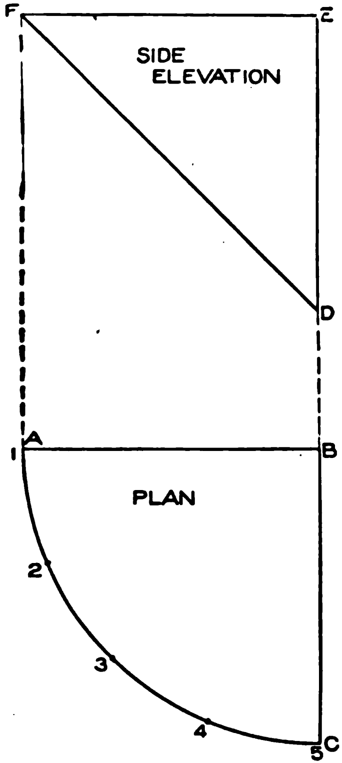


Fig. 20.

When joining a faucet or stop cock to a sheet-metal tank it is usual to strengthen the joint by means of a conical "boss," which is indicated by A in Fig. 22. In this problem the cone method is employed, using principles similar to those used in developing a frustum of a cone intersected by any line. Therefore in Fig. 23 let A B represent the part plan of the tank, C portion of the faucet extending back to the tank line, and F G H I the conical "boss" to fit around a faucet. When drawing this problem make the radius of the tank D A equal to 3½ inches, and from D draw the vertical line D E. Make the distance from G to H equal to 2¾ inches, the diameter of the faucet F I 1¼ inches and the vertical height K C 1½ inches Draw a line from G to H intersecting the center line D E at K. Then using K as center describe the half section G J H as shown. Divide J H into equal parts shown from 1 to 4, from which drop vertical lines intersecting the line G H as shown, from which draw radial lines to the apex E cutting the plan line

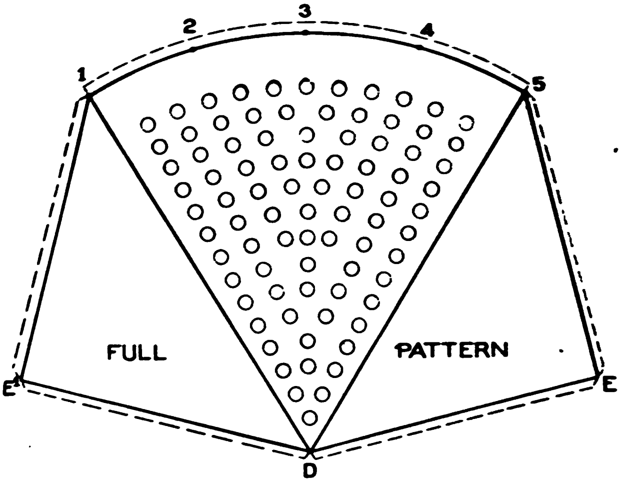


Fig. 21.

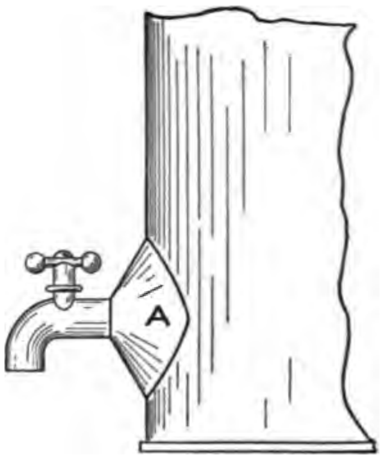


Fig. 22.

of the tank A B as shown. From these intersections draw horizontal lines intersecting the side of the cone H I at 1, 2′, 3′, and 4′. Now use E as center, and with radius equal to E 1 describe the

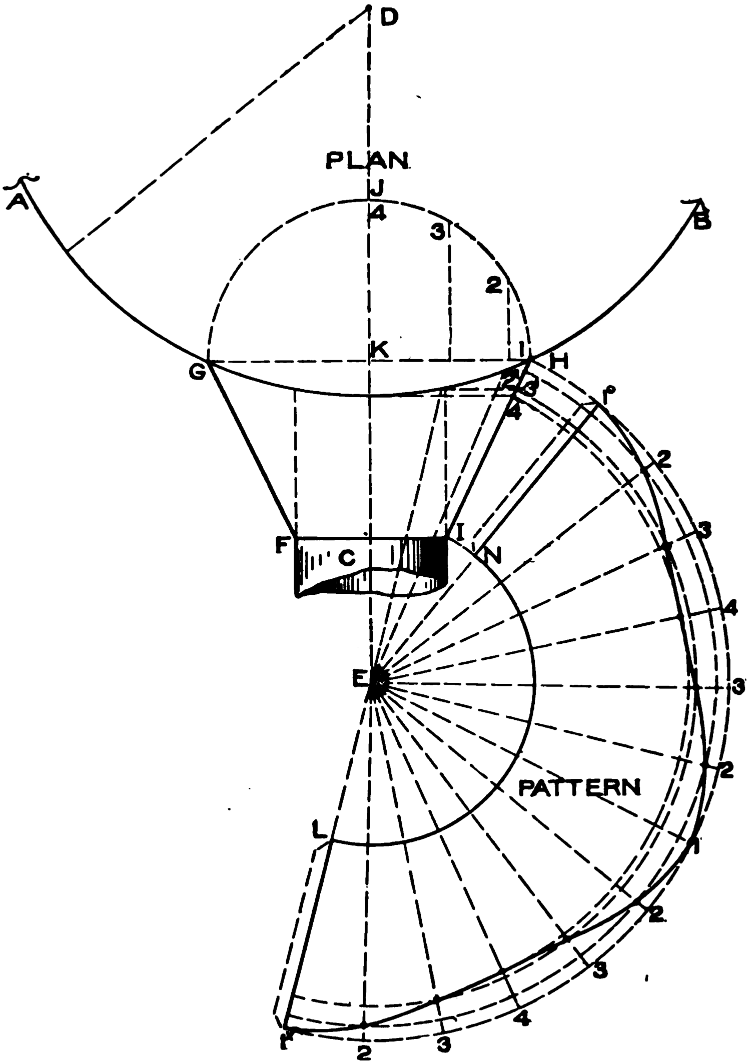


Fig. 23.

arc 1°-1^x as shown. Draw a line from 1° to E, and starting from 1° set off on 1°-1^x four times the number of spaces contained in

J H in plan, as shown by similar numbers on $1^\circ\ 1^x$. Draw a line from 1^x to E, and with E I as radius describe the arc N L intersecting the radial lines 1° E and 1^x E at N and L respectively. From the various numbers on the arc $1^\circ\ 1^x$ draw radial lines to the apex E; and using E as center and with radii equal to E 4′, E 3′, and E 2′, draw arcs intersecting similarly numbered radial lines as shown. Trace a line through points thus obtained; then will N 1° 1 1^x L be the pattern for the "boss."

In Fig. 24 is shown what is known as a hip bath. In drawing out the problem for practice the student should remember that it is similar to the preceding one, the only difference being in the outline of the cone. Make the top of the cone I B in Fig. 25 equal to 3¼ inches, the bottom C D 1¾ inches, the vertical height from K to 5′ 2½ inches, the diameter of the foot E F 2¼ inches, and the vertical height 5′–5″ ¼-inch. Through the center of the cone draw the center line K L, and at pleasure draw the outline of the bath as shown by A J B. It is immaterial of what outline this may be, the principles that follow being applicable to any case. Thus, in the side elevation, extend the lines B C and A D until they intersect the center line at L. In similar manner extend the sides of the foot piece E D and F C until they intersect the center line at R. Now with 5′ as center and with radius equal to 5′ D or 5′ C, describe the half section C H D, which divide into equal spaces as shown by the small figures 1 to 9. From the points of division erect vertical lines meeting the base line of the bath D C at points 1, 2′, 3′, etc., to 9. From the apex L and through these points draw radial lines intersecting the outline B J A, from which horizontal lines are drawn intersecting the side of the bath B C as shown from 1 to 9. For the pattern for the body use L as center, and with L C as radius draw the arc F L^1. Now starting at any point, as 1, set off on F L^1 twice the stretchout of D H C as shown by similar numbers on the arc F L^1. From the apex L and through the small figures draw radial lines, which intersect by arcs

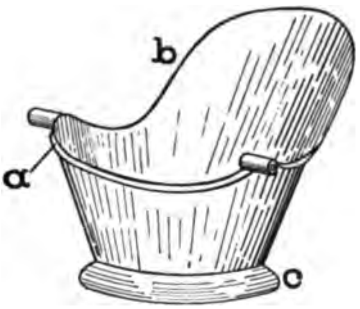


Fig. 24.

struck from L as center with radii equal to similarly numbered intersections on B C. Trace a line through points thus obtained, and L^1 M N P F will be the pattern for the body of the bath, to which laps should be added at the bottom and sides for seaming.

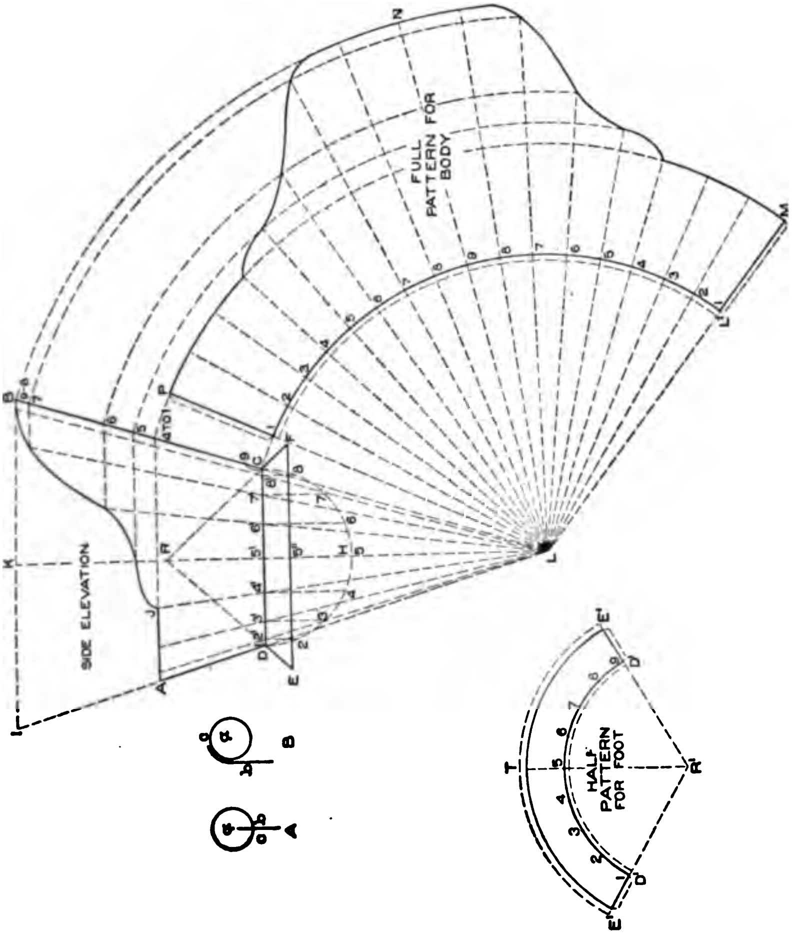


Fig. 25.

The pattern for the foot is obtained by using as radii R D and R E, and striking the pattern using R^1 as center, the half pattern being shown by E^1 T E^1 D^1 D^1, and the distance D^1 D^1 being equal to the stretchout of the half section D H C in side elevation.

It is usual to put a bead along the edges of the top of a bath as shown at *a* and *b* in Fig. 24. For this purpose tubing is sometimes used, made of brass, zinc, or copper and bent to the required shape; or zinc tubes may be rolled and soldered by hand, filled with heated white sand or hot rosin, and bent as needed. The tube or bead can be soldered to the body as shown in (A) in Fig. 25. Here *a* represents the bead, in which a slot is cut as *c*, and which is then slipped over the edge of the bath and soldered. Another method is shown in (B), in which the bath body *b* is flanged over the bead *a* and soldered clean and smooth at *c*, being then scraped and sandpapered to make a smooth joint. A wired edge is shown at *c* in Fig. 24, for which laps must be allowed as shown in Fig. 25 on the half pattern for foot.

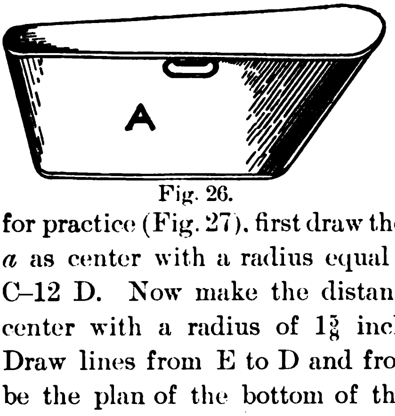


Fig. 26.

In Fig. 26 is shown the perspective view of a bath tub; these tubs are usually made from IX tin or No. 24 galvanized iron. The bottom and side seams are locked and thoroughly soldered, while the top edge is wired with handles riveted in position as shown at A. The method used in developing these patterns will be the cone method and triangulation. In drawing this problem for practice (Fig. 27), first draw the center line W 8 in plan; and using *a* as center with a radius equal to 1½ inches draw the semicircle C–12 D. Now make the distance *a* to *b* 4 inches; and using *b* as center with a radius of 1⅝ inches draw the semicircle E–7–H. Draw lines from E to D and from C to H. D E 7 H C 12 D will be the plan of the bottom of the bath. In this case we assume that the flare between the top and bottom of the narrow end of the bath should be equal; therefore using *a* as center and with a radius equal to 1⅝ inches draw the semicircle A W B. At the upper end of the bath the flare will be unequal; therefore from *b* measure a distance on line W 8 of 1 inch and obtain *c*, which use as center, and with a radius equal to 2 inches describe the arc F 8 G. Draw lines from F to A and from B to G; and A F 8 G B W A will be the plan of the top of the bath. Now project the side elevation from the plan as shown by the dotted lines, making the slant height from I to R 2⅛ inches and from J to K 3⅛ inches; draw a line from K to R, and J K R I will be the side elevation of the bath tub. In constructing the bath in practice, seams are located at H G, F E,

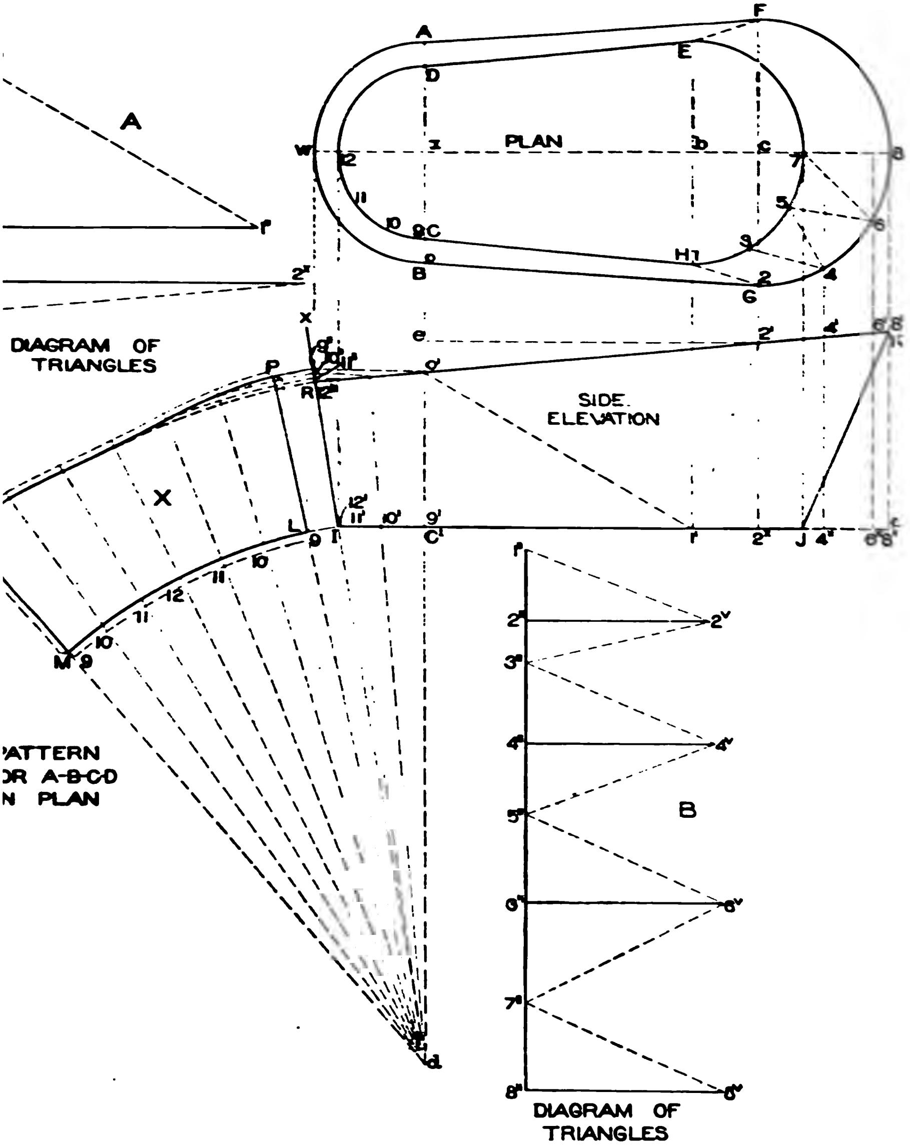


Fig. 27.

A D, and C B in plan, thus making the tub in four pieces

The lower end of the bath will be developed by the cone method as in the last two problems. From the center *a* drop a line indefinitely as shown. Extend the side R I of the side elevation until it meets the center line *a d* at *d*. Now divide the quarter circle 12–9 in plan into equal spaces as shown by the small figures 9, 10, 11, and 12, from which drop vertical lines (not shown) intersecting the bottom of the bath tub in elevation from 9′ to 12′. Then through these points from *d* draw lines intersecting the top line of the bath R K as shown, from which draw horizontal lines intersecting the side I–R extended as I X at points 9″ to 12″. Then using *d* as center and *d* I as radius, describe the arc I M, upon which place the stretchout of D 12 C in plan, as shown by similarly numbered points on L M. Through these points from *d* draw radial lines, which intersect by arcs drawn from similarly numbered intersections on I R extended, using *d* as center. Trace a line as shown, and L M N P will be the pattern for the lower end of the tub A B C D in plan. Laps should be allowed for wiring and seaming.

As the patterns for the upper end and sides will be developed by triangulation, diagrams of triangles must first be obtained, for which proceed as follows: Divide both of the quarter circles H 7 and G 8 in plan into the same number of spaces as shown respectively from 1 to 7 and from 2 to 8. Connect these numbers by dotted lines as shown from 1 to 2, 2 to 3, 3 to 4, etc. From the various points 2, 4, 6, and 8 representing the top of the bath, drop lines meeting the base line J *f* in elevation at 2^x, 4^x, 6^x, and 8^x, and cutting the top line of the bath at 2′, 4′, 6′, and 8′. Then will the dotted lines in plan represent the bases of the triangles, which will be constructed, whose altitudes are equal to the various heights in elevation. Take the various distances 1 to 2, 2 to 3, 3 to 4, 4 to 5, etc., in plan up to 8, and place them on the vertical line 1″–8″ in (B) as shown from 1″ to 2″, 2″ to 3″, 3″ to 4″, 4″ to 5″, etc., up to 8″. For example, to obtain the true length of the line 6–7 in plan, remembering that the points having even numbers represent the top line of the bath and those having uneven numbers the base line, draw at right angles to 1″–8″ in (B), from 6″, a line equal in height to 6^x–6′ in elevation, and draw a line from 6^v to 7″ in (B), which is the length desired. For the true length of 6–5 in plan it is necessary only to take this distance place it from 6″ to 5″ in (B) and draw a line from 6^v to 5″. In this way each altitude answers for two triangles. In plan draw a line from 1 to 0. Then will two more triangles be necessary, one on the line 1–0, and the other on B G or 0–2. From 2′ in elevation draw a horizontal line, as 2′ *e*, intersecting the vertical line dropped from 0 at *e*. Now take the distances 0 1 and 0 2, and place them in (A) as shown by the horizontal lines 0″–1″ and 0^x–2^x respectively. At right angles to both lines at either end draw the vertical lines 0″–0‴ and 0^x–0^v equal in height respectively to C^1 0′ and *e* 0′ in elevation. Draw in (A) lines from 2^x to 0^v and from 1″ to 0‴, which are the desired lengths. Before proceeding with the pattern, a true section must be obtained on 2′–8′ in side elevation. Take the various distances 2′ to 8′ and place them on the line 2′–8′ in Fig. 28. At right angles to 2′–8′ and through the small figures draw lines as shown. Now measuring in each and every instance from the center line in plan in Fig. 27, take the various distances to points 2, 4, and 6 and place them on similarly numbered lines in Fig. 28, measuring in each case on either side of the line 2′–8′, thus obtaining the intersections 2–4–6. A line traced through these points will be the true section on 2′–8′ in elevation in Fig. 27.

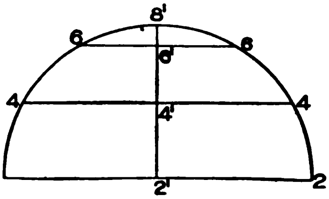


Fig. 28.

For the pattern for the upper end of the tub proceed as follows: Take the distance of 7″–8^v in (B) and place it on the vertical line 7–8 in Fig. 29. Then using 8 as center and with a radius equal to 8′–6 in Fig. 28, describe the arc 6 in Fig. 29, which intersect by an arc struck from 7 as center and with 7″–6^v in (B) in Fig. 27 as radius. Then using 7–5 in plan as radius, and 7 in Fig. 29 as center, describe the arc 5, which intersect by an arc struck from 6 as center and with 6^v–5″ in (B) in Fig. 27 as radius. Proceed in this manner, using alternately as radii first the divisions in Fig. 28, then the length of the slant lines in (B) in Fig. 27, the divisions on 7 H in plan, then again the slant lines in B, until the line 1–2 in Fig. 29 is obtained. Trace a line through points thus obtained, as shown by 2–8–7–1. Trace this opposite the line 8–7, as shown by 2′ 1′. Then will 2–8–2′–1′–7–1 be the desired pattern, to which laps must be allowed.

For the pattern for the side of the bath draw any line 9–1 in Fig. 30 equal to 9–1 in plan in Fig. 27. Now with a radius equal to 9–P in the pattern X and with 9 in Fig. 30 as a center, describe the arc 0, which intersect by an arc struck from 1 as center and with 1″–0‴ in (A) in Fig. 27 as radius. Now taking a radius equal to 0^v–2^x in (A) with 0 in Fig. 30 as center, describe the arc 2, which intersect by an arc struck from 1 as center, and with 1–2 in Fig. 29 as radius. Draw lines from corner to corner in Fig. 30, which gives the desired pattern, to which laps are added for seaming and wiring.

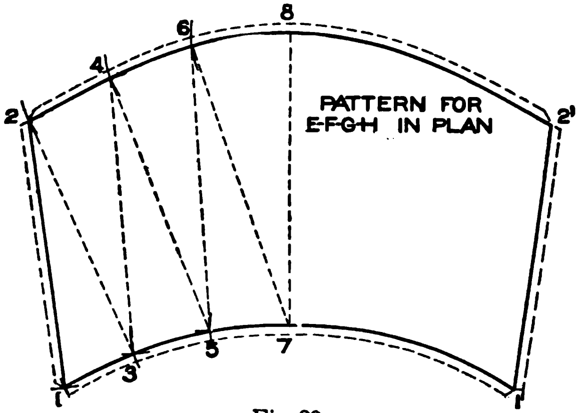


Fig. 29.

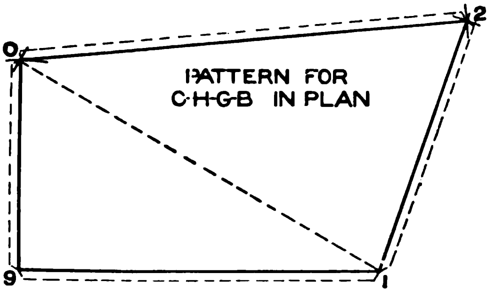


Fig. 30.

In Fig. 31 is shown a perspective view of a funnel strainer pail. These pails are usually made from IX bright tin, and the same principles as are used in the development of the pattern are applicable to similar forms, such as buckets, coal hods, chutes, etc. This problem presents an interesting study in triangulation, the principles of which have been explained in previous problems. First draw the center line C I in Fig. 32, at right angles to which draw H E and H F each equal to 1¼ inches. Make the vertical height H C 3¼ inches and C D 2 inches. Now make the vertical heights measuring from C G, to A, and to B respectively 1¼ inches, and 1½ inches. Make the horizontal distance from C to G 2¾ inches, the diameter from G to A 1⅜ inches, and from A to B ¾-inch, and draw a line from B to C. Connect points by lines; then will A B C D E F G be the side elevation of the pail. In its proper position below F E, with J as center, draw the plan K L M N. Also in its proper position draw the section on A G as O P R S. Now draw the rear elevation making G^1 U and G^1 V each equal to H E, and 1″ T and 1″–1′ each equal to C D. Project a line from B in side, intersecting the center line in rear at 4′. Then through the three points 1′ 4′ T draw the curve at pleasure, which in this case is struck from the center *a*. W Y X Z represents the opening on G A in side obtained as shown by the dotted lines but having no bearing on the patterns. Pails of this kind are usually made from two pieces, with seams at the sides, as in Fig. 31. The pattern then for the back shown by C D E H in side elevation in Fig. 32 will be obtained by the cone method, struck from the center I, the stretchout on E^1 E^2 in the pattern being obtained from the half plan. The pattern for C D E H is shown with lap and wire allowances by D^1 D^2 E^2 E^1 and needs no further explanation.

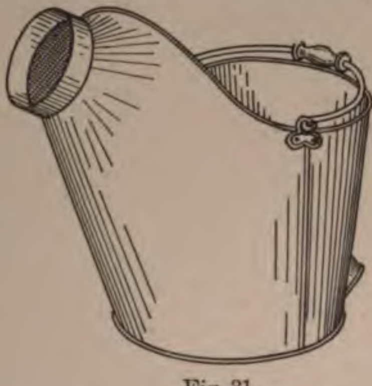


Fig. 31.

The front part of the pail shown by A B C H F G will be developed by triangulation, but before this can be done a true section must be obtained on B C, and a set of sections developed as follows: Divide one-half of 1′ 4′ T in rear elevation into equal parts as shown from 1′ to 4′, from which draw horizontal lines intersecting the line B C as shown. From these intersections lines are drawn at right angles to B C equal in length to similarly numbered lines in rear as 3′–3″, 2′–2″, and 1′–1″. Trace a line as shown, so that C 1‴ 2‴ 3‴ 4‴ will be the true half section on B C. To avoid a confusion of lines take a tracing of A B C H F G and place it as shown by similar letters in Fig. 33. Now take tracings of the half sections in Fig. 32, as H E D C, C 1‴ B, P O S, and the quarter plan N J M, and place them in Fig. 33 on similar lines on which they represent sections as shown respectively by H 9′ 8′ C, C 8 B, A 3 G, and F 9 H. Divide the half section

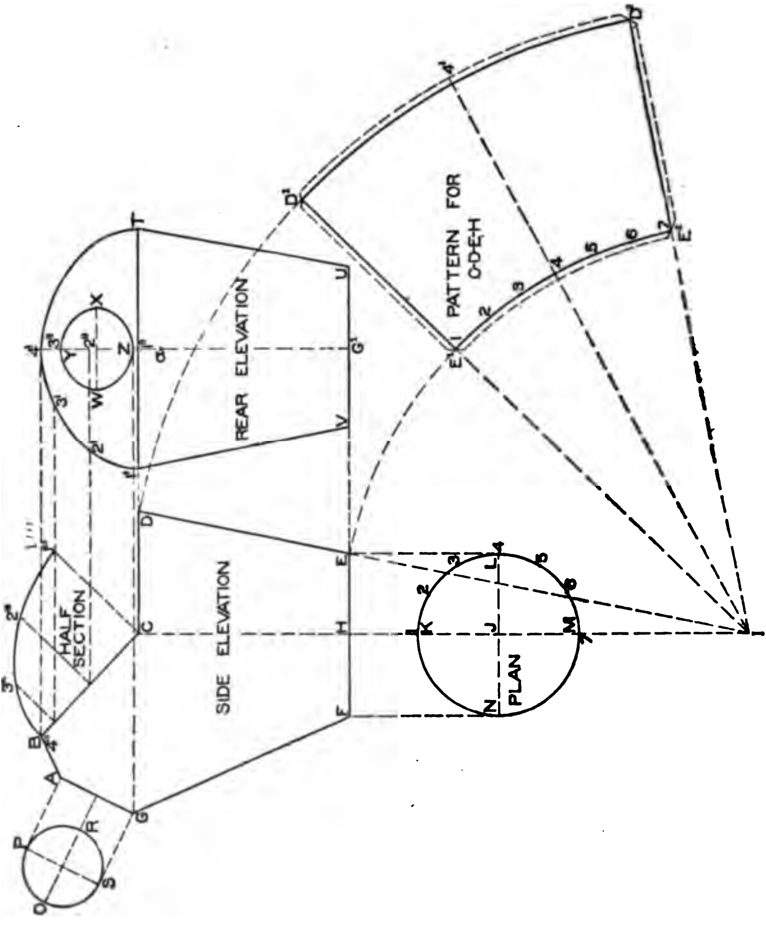
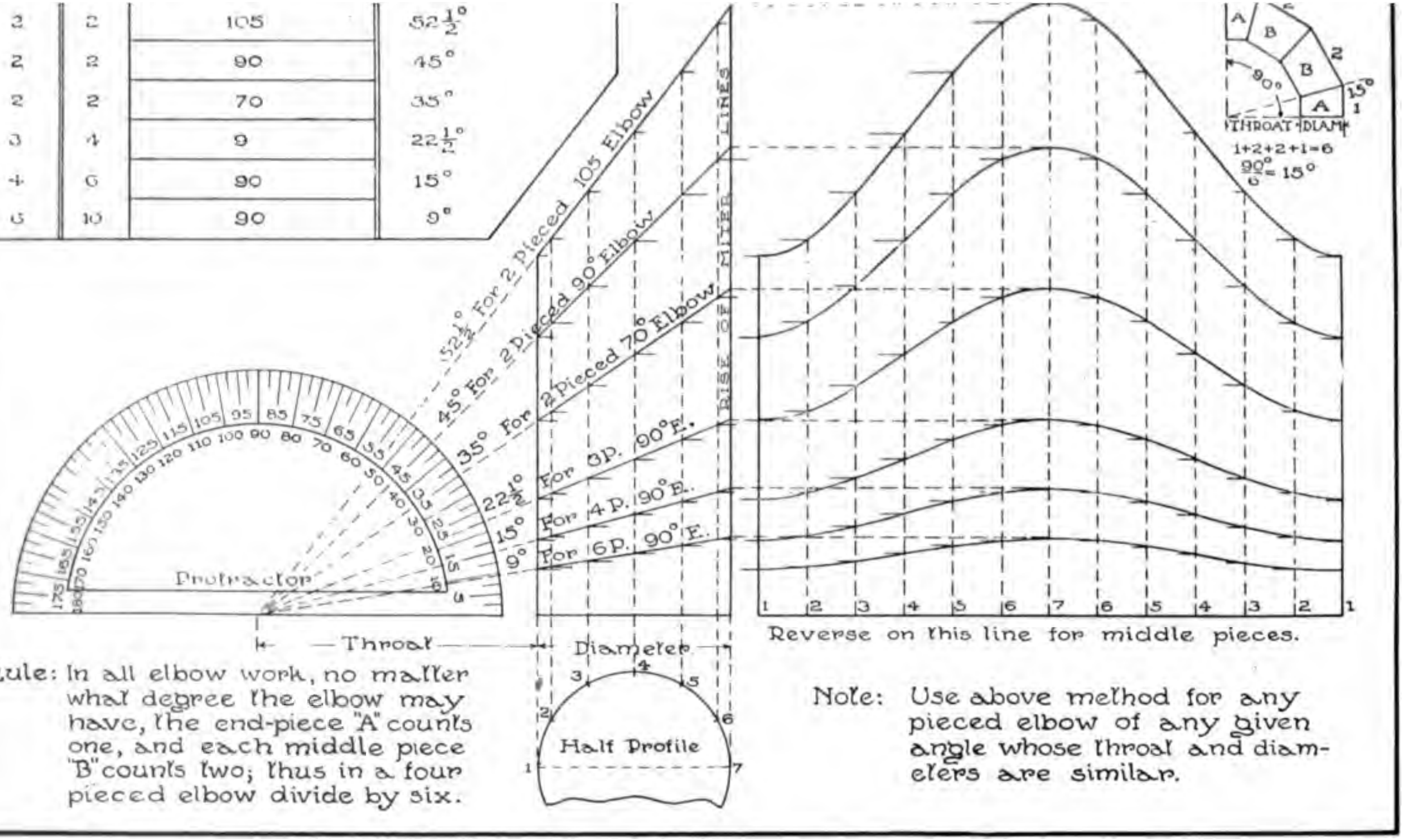


Fig. 32.

A 3 G into 6 equal parts as shown by the small figures 1 to 5. As this half section is divided into 6 parts, then must each of the sections B 8 C and F 9 H be divided into 3 parts as shown respectively from 6 to 8 and 9 to 11. As C 8′ and H 9′ are equal respectively to C 8 and H 9 they are numbered the same as shown.

2	2	105	$52\frac{1}{2}°$
2	2	90	45°
2	2	70	35°
3	4	9	$22\frac{1}{2}°$
4	6	90	15°
5	10	90	9°



Reverse on this line for middle pieces.

Rule: In all elbow work, no matter what degree the elbow may have, the end-piece "A" counts one, and each middle piece "B" counts two; thus in a four pieced elbow divide by six.

Note: Use above method for any pieced elbow of any given angle whose throat and diameters are similar.

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ASTOR, LENOX AND
TILDEN FOUNDATIONS

Now at right angles to G A, B C, C H, and H F, and from the various intersections contained in the sections G 3 A, B 8 C, C 8′ 9′ H, and H 9 F, draw lines intersecting the base lines of the sections G A, B C, C H, and H F at points shown from 1′ to 11′. Now draw dotted lines from B to 5′ to 6′ to 4′ to 7′ to E to C, and then from H to E to 10′ to 2′, etc until all the points are connected as shown. These dotted lines represent the bases of the sections whose altitudes are equal to similar numbers in the various sections.

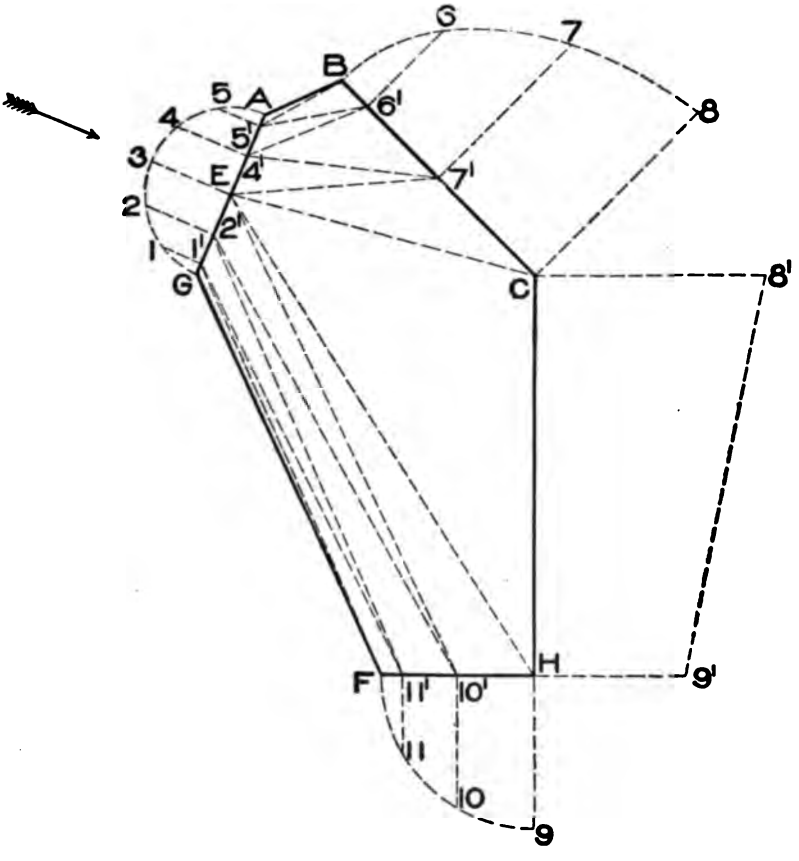

Fig. 33.

In order that the student may thoroughly understand this method of triangulation as well as similar methods that will follow in other problems, the model in Fig. 34 has been prepared, which shows a perspective of Fig. 33 with the sections bent up in their proper positions. This view is taken on the arrow line in Fig. 33, the letters and figures in both views being similar. For the true sections on the dotted lines in C E A B in Fig. 33, take the lengths of the dotted lines C E, E 7′, 7′ 4′, etc., and place them on the horizontal line in Fig. 35 as shown by similar letters and figures. From these small figures, at right angles to the horizontal line, erect the vertical heights C 8, E 3, 7′ 7, etc., equal to similar vertical heights in the sections in Fig. 33. Connect these points in Fig. 35 by dotted lines as shown, which are the desired true distances.

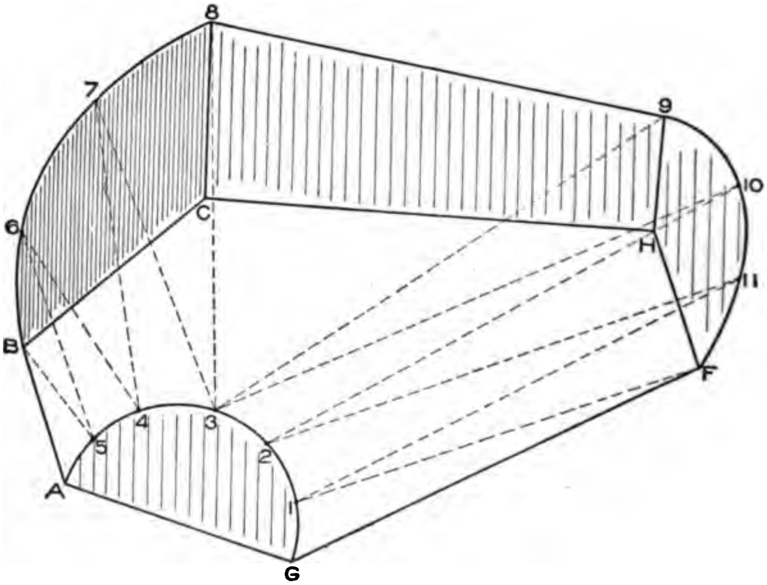

Fig. 34.

In Fig. 36 are shown the true sections on dotted lines in G E H F in Fig. 33, which are obtained in precisely the same manner, the only difference being that one section is placed inside of another in Fig. 36. For the pattern proceed as is shown in Fig. 37. Draw any vertical line as G F equal to G F in Fig. 33. With radius equal to G 1 and with G in Fig. 37 as center describe the arc 1, which intersect by an arc struck from F as center and with a radius equal to F 1 in Fig. 36. Now with F 11 in Fig. 33 as radius and F in Fig. 37 as center, describe the arc 11, which is intersected by an arc struck from 1 as center and with 1–11 in Fig 36 as radius. Proceed in this manner until the line 3–9 in Fig. 37 has been obtained. Then using 8′–9′ in Fig. 33 as radius and 9 in Fig. 37 as center, describe the arc 8, which is intersected by an arc struck from 3 as center and with 3–8 in Fig. 35 as radius. Now use alternately as radii, first the divisions in B 8 C in Fig. 33, then the length of the slant lines in Fig. 35, the divisions in E 3 A in Fig. 33, and again the distances in Fig. 35, until the line B A in Fig. 37 has been obtained, which is obtained from B A in Fig. 33. Trace a line through points thus obtained in Fig. 37 as shown by A B 8 9 F G A. Trace this half pattern opposite the line G F. Then will B A G A¹ B¹ 8¹ 9¹ F 9 8 be the pattern for the front half of the pail. If for any reason the pattern is desired in one piece, then trace one-half of D¹ D² E² E¹ in Fig. 32 on either side of the pattern in Fig. 37 as shown by the dotted lines 8′ D¹ E¹ 9¹ and 9 E D 8. Allow edges for wiring and seaming.

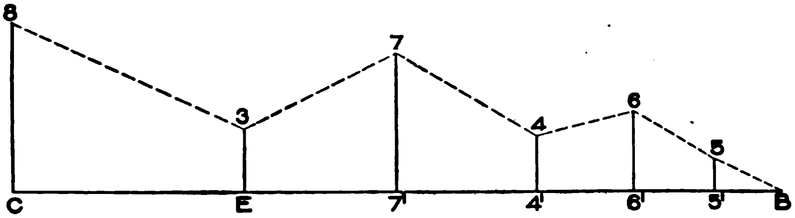

Fig. 35.

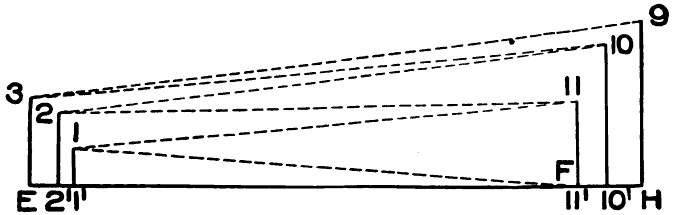

Fig. 36

Fig 38 shows the method for obtaining the pattern for an Emerson ventilator shown in Fig. 39.

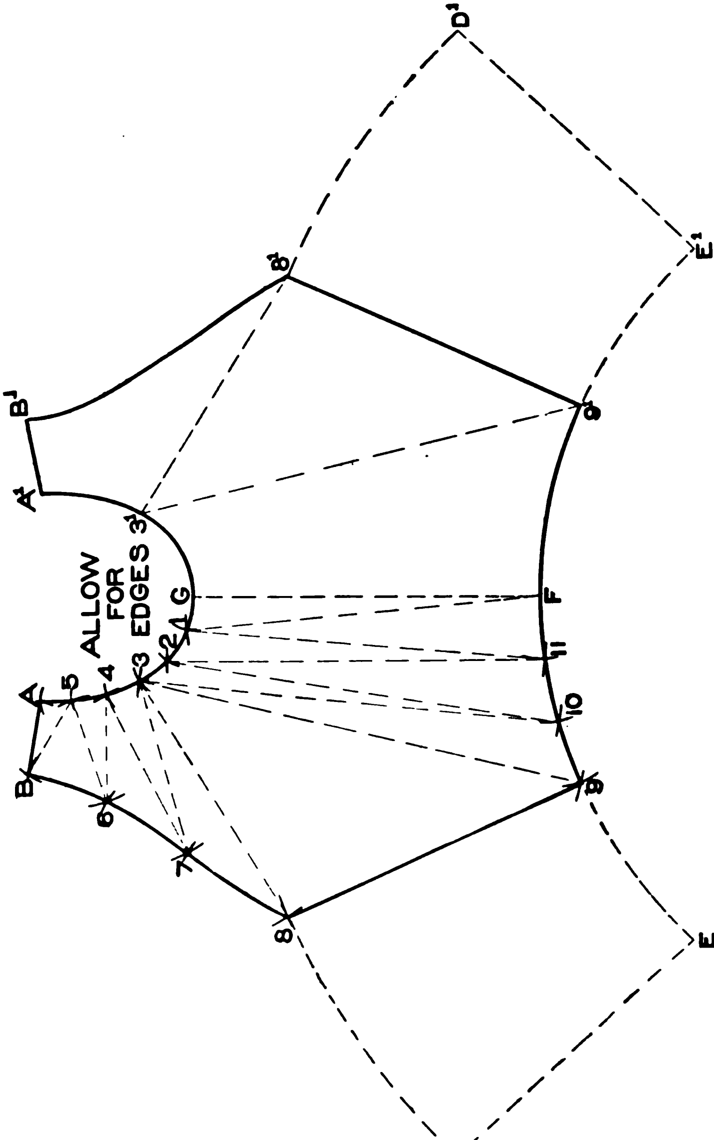

Fig. 37.

While the regular Emerson ventilator has a flat disc for a hood it is improved by placing a cone and deflector on the top as shown. To make the patterns, proceed as shown in Fig. 38. First draw the center line *a b*, on either side of which lay off

1½ inches, making the pipe A, 3 inches in diameter. The rule usually employed is to make the diameter of the lower flare and upper hood twice the diameter of the pipe. Therefore make the diameter of *s d* 6 inches. From *s* and *d*, draw a line at an angle of 45° to intersect the line of the pipe at *t* and *i*; this completes B. Measure 2 inches above the line *t i* and make *u m* the same diameter as *s d*. Draw the bevel of the deflector so that the apex will be ½ inch above the line *t i* and make the apex of the hood the same distance above *u m* as the lower apex is below it. Then draw lines as shown which complete C and D. Now with *c* as a center and radii equal to *c e* and *c d* draw the quarter circles *e f* and *d h* respectively, which represent the one-quarter pattern for the horizontal ring closing the bottom of the lower flare. For the pattern for the hood, use *l* as a center and *l m* as a radius. Now draw the arc *m m'*. Take the stretchout

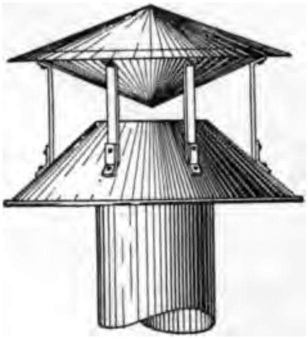

Fig. 39.

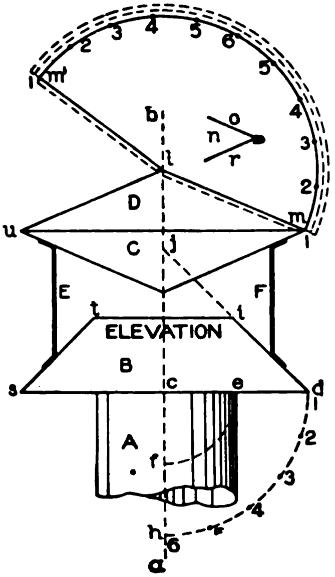

Fig. 38.

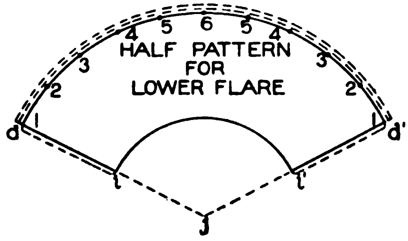

Fig. 40.

of the quarter circle 1 to 6 on *d h*, and place twice this amount on *m m'* as shown from 1-6-1. Draw a line from 1 to *l*. Then *m'* 6 *m l*, will be the half pattern for the hood. As the deflector has the same bevel as the hood, the hood pattern will also answer for the deflector.

When seaming the hood and deflector together as shown at *n*, the hood *o* is double-seamed to the deflector at *r*, which allows the water to pass over; for this reason allow a double edge on the pattern for the hood as shown, while on the deflector but a single edge is required. Edges should also be allowed on *e d h f*.

For the pattern for the lower flare, extend the line *d i* until it intersects the center line at *j*. Then with radii equal to *j i* and *j d* and with *j* in Fig. 40 as center describe the arcs *i i'* and *d d'*. On one side as *d* draw a line to *j*. Then set off on the arc *d d'* twice the number of spaces contained in *d h* in Fig. 38 as shown in Fig. 40. Draw a line from *d'* to i and allow edges for seaming. Then *d d' i' i* will be the half pattern for the lower flare.

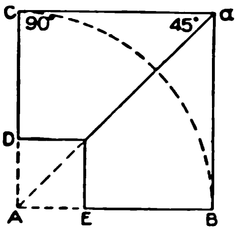

Fig. 41.

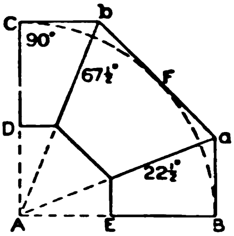

Fig. 42.

The braces or supports. E and F, Fig. 38, are usually made of galvanized band iron bolted or riveted to hood and pipe. The hood D must be water tight, or the water will leak into the deflector, from which it will drip from the apex inside the building.

Elbows. There is no other article in the sheet-metal worker's line, of which there are more made in practice than elbows. On this account rules will be given for constructing the rise of the miter line in elbows of any size or diameter, also for elbows whose sections are either oval, square or round, including tapering elbows Before taking up the method of obtaining the patterns, the rule will be given for obtaining the rise of the miter line for any size or number of pieces. No matter how many pieces an elbow has, they join together and form an angle of 90°. Thus when we speak of a two-pieced, three-pieced, four, five or six-pieced elbow, we understand that the right-angled elbow is made up of that number of pieces. Thus in Fig. 41 is shown a two-pieced elbow placed in the quadrant C B, which equals 90° and makes C A B a right angle. From A draw the miter line A *a* at an angle of 45° to the base line A B. Then parallel to A B and A C and tangent to the quadrant at C and B draw lines to intersect the miter line, as shown. Knowing the diameter of the pipe as C D or E B draw lines parallel to the arms of the pipe, as shown. Then C B E D will be a two-pieced elbow, whose miter line is an angle of 45°.

In a similar manner draw the quadrant B C, Fig. 42, in which it is desired to draw a three-pieced elbow. Now follow this simple rule, which is applicable for any number of pieces: Let the top piece of the elbow represent 1, also the lower piece 1, and for every piece between the top and bottom add 2. Thus in a three-pieced elbow:

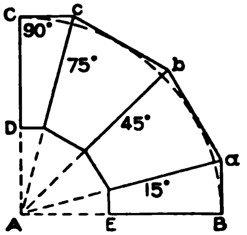

Fig. 43.

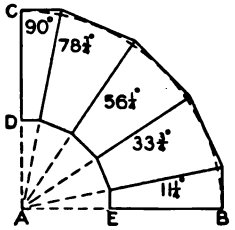

Fig. 44.

Top piece equals	1
Bottom piece equals	1
One piece between	2
Total equals	4

Now divide the quadrant of 90° by 4 which leaves 22½°. As one piece equals 22½°, draw the lower miter line A *a* at that angle to the base line A B. Then as the middle piece represents two by the above rule and equals 45°, add 45 to 22½ and draw the second miter line A *b*, at an angle of 67½° to the base line A B. Now tangent to the quadrant at C and B draw the vertical and horizontal lines shown, until they intersect the miter lines, from which intersections draw the middle line, which will be tangent to the quadrant at F. C D and B E show the diameters of the pipe, which are drawn parallel to the lines of the elbow shown.

Fig. 43 shows a four-pieced elbow, to which the same rule is applied. Thus the top and bottom piece equals 2 and the two middle pieces equal 4; total 6. Now divide the quadrant of 90° by 6. $\frac{90}{6} = 15$. Then the first miter line A *a* will equal 15°, the second A *b* 45°, the third A *c* 75°, and the vertical line A C 90°.

The last example is shown in Fig. 44, which shows a five-pieced elbow, in which the top and bottom pieces equal 2, the 3 middle pieces 6; total 8. Divide 90 by 8. $\frac{90}{8} = 11\frac{1}{4}$. Then the first miter line will equal 11¼°, the second 33¾°, the third 56¼°, and the fourth 78¾°. By using this method an elbow having any number of pieces may be laid out. When drawing these miter lines it is well to use the protractor shown in Fig. 45, which illustrates how to lay out a three-pieced elbow. From the center point A of the protractor draw lines through 22½°, and 67½°. Now set off A *a*, and the diameter of the pipe *a b*. Draw vertical lines from *a* and *b* to the miter line at *c* and *d*. Lay off similar distances from A to *a′* to *b′* and draw horizontal lines intersecting the 67½° miter line at *c′* and *d′*. Then draw the lines *d d′* and *c c′* to complete the elbow. In practice, however, it is not necessary to draw out the entire view of the elbow; all that is required is the first miter line, as will be explained in the following problems.

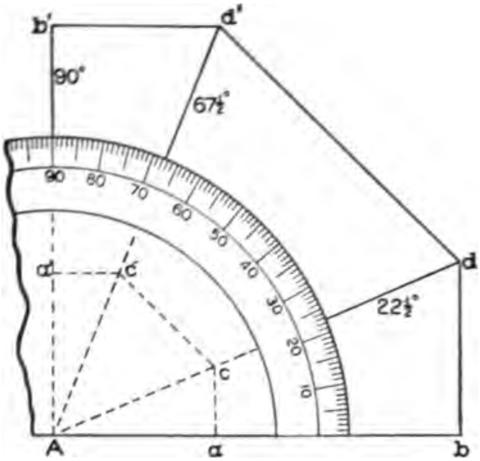

Fig. 45.

EXERCISES FOR PRACTICE.

1. Make the diameter of the pipe 1¾ inches and the distances from A to E 1½ inches in Figs. 41 to 44 inclusive.

To obtain the pattern for any elbow, using but the first miter line, proceed as follows: In Fig. 46 let A and B represent respectively a two- and three-pieced elbow for which patterns are desired. First draw a section of the elbow as shown at A in Fig. 47 which

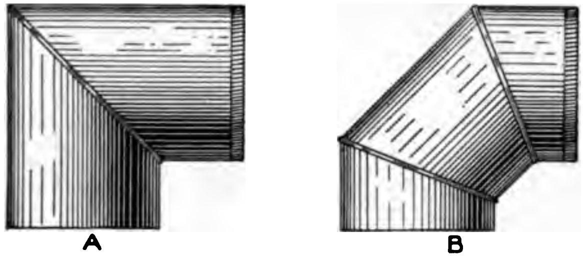

Fig. 46.

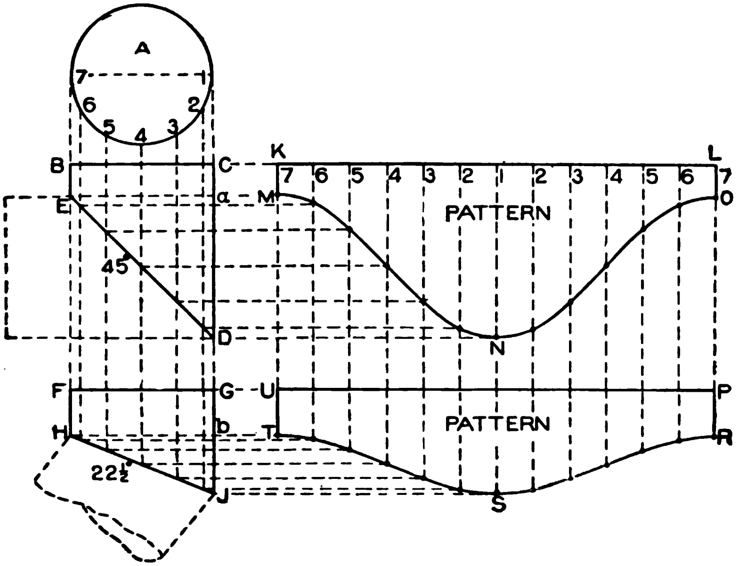

Fig. 47.

is a circle 3 inches in diameter; divide the lower half into equal spaces and number the points of division 1 to 7. Now follow the rule previously given: The top and bottom piece equals 2; then for a two-pieced elbow divide 90 by 2. In its proper position below the section A draw B C D E making E D 45°. From the various points of intersection in A drop vertical lines intersecting E D as

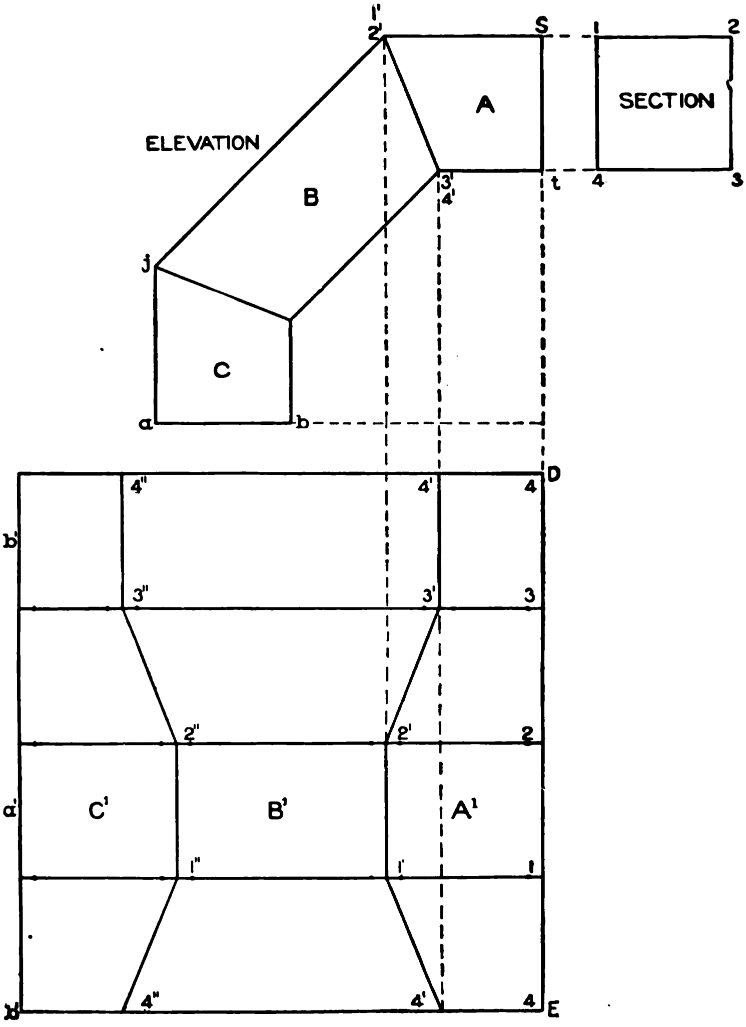

Fig. 48.

shown. In line with B C draw K L upon which place twice the number of spaces contained in the section A as shown by similar figures on K L; from these points drop perpendiculars to intersect with lines drawn from similar intersections on E D, parallel to K L. Trace a line through points shown; then K L O N M will be the pattern. To this laps must be allowed for seaming.

Now to obtain the pattern for a three-pieced elbow, follow the rule. Top and bottom pieces equal 2, one middle piece equals 2; total 4. $\frac{90}{4} = 22\frac{1}{2}$. Therefore in line with the section A below the two-pieced elbow draw F G J H, making H J at an angle of $22\frac{1}{2}^\circ$ to the line H *b*. Proceed as above using the same stretchout lines; then U P R S T will be the desired pattern. It should be understood that when the protractor is used for obtaining the angle as shown in Fig. 45, the heights *a c* and *b* d measured from the horizontal line form the basis for obtaining the heights of the middle pieces, inasmuch as they represent one-half the distance; for that reason the middle pieces count 2 when using the rule. Therefore, the distances F H and G J (Fig. 47), represent one-half of the center piece and U T S R P one-half the pattern for the center piece of a three-pieced elbow.

Fig. 48 shows how the patterns are laid into one another, to prevent waste of metal when cutting. In this example we have a three-pieced elbow whose section is 2 × 2 inches. It is to be laid out in a quadrant whose radius is 5 inches. Use the same principles for square section as for round; number the corners of the section 1 to 4. In line with S *t* draw D E upon which place the stretchout of the square section as shown by similar numbers on D E; from which draw horizontal lines which intersect lines drawn parallel to D E from the intersections 1′ 2′ and 3′ 4′ in A in elevation, thus obtaining similar points in the pattern. Then A^1 will be the pattern for A in elevation. For the pattern for B simply take the distance from 2′ to *j* and place it on the line 4 4′ extended in the pattern on either side as shown by 4′ 4″ on both sides. Now reverse the cut 4′ 2′ 4′ and obtain 4″ 2″ 4″. By measurement it will be found that 4′ 4″ is twice the length of 2′ 2 as explained in connection with Figs. 45 and 47. Make the distance from 1″ to *a′* the same as *j* to *a* in C and draw the vertical line *b′ b′* intersecting the lines 4 4″ extended on both sides. Then A^1, B^1, and C^1 will be the patterns in one piece minus the edges for seaming which must be allowed between these cuts; this would of course make the lengths b′ 4″, 4″ 4′ and 4′ 4 as much longer as the laps would necessitate.

This method of cutting elbows in one piece, from one square is applicable to either round, oval or square sections.

In Figs. 49 and 50 are shown three-pieced elbows such as are used in furnace-pipe work and are usually made from bright tin. Note the difference in the position of the sections of the two elbows. In Fig. 49 *a b* is in a vertical position, while in Fig. 50 it is in a horizontal position. In obtaining the patterns the same rule is employed as in previous problems, care being taken when developing the patterns for Fig. 49 that the section be placed as in Fig. 51 at A; and when developing the patterns for Fig. 50, that the section be placed as shown at A in Fig. 52.

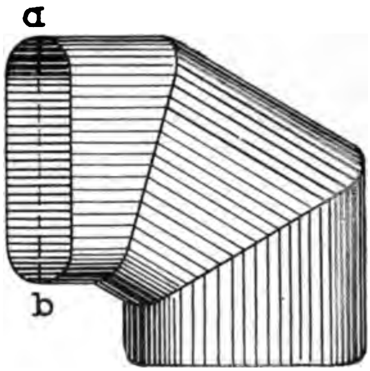

Fig. 49.

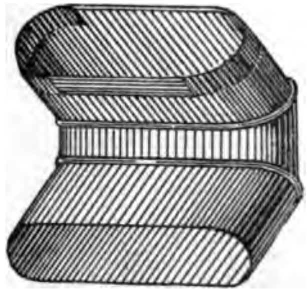

Fig. 50.

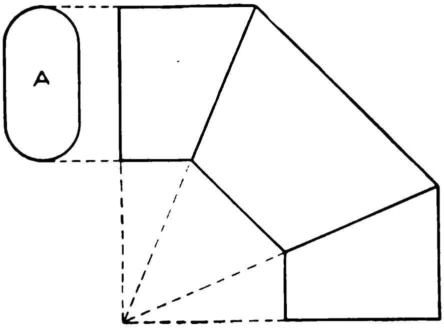

Fig. 51.

Fig. 53 shows a tapering two-pieced elbow, round in section. The method here shown is short and while not strictly accurate, gives good results. It has been shown in previous problems on Intersections and Developments that an oblique section through the opposite sides of a cone is a true ellipse. Bearing this in mind it is evident that if the frustum of the cone H I O N, Fig. 54, were a solid and cut obliquely by the plane J K and the several parts placed side by side, both would present true ellipses of exactly the same size, and if the two parts were placed together again turning the upper piece half-way around as shown by J W M K, the edges of the two pieces from J to K would exactly coincide. Taking advantage of this fact, it is necessary only to ascertain the angle of the line J K, to produce the required angle, between the two pieces of the elbow, both of which have an equal flare. The angle of the miter line, or the line which cuts the cone in two parts, must be found accurately so that when joined together an elbow will be formed having the desired angle on the line of its axis.

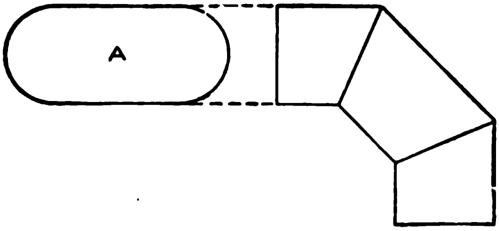

Fig. 52.

Therefore draw any vertical line as A B. With C as a center describe the plan of the desired diameter as shown by E D F B. At right angles to A B draw the bottom line of the elbow H I equal to E F, or in this case, 3 inches. Measuring from the line H I on the line A B the height of the frustum is 5 inches. Through X′ draw the upper diameter O N, 1½ inches. Extend the contour lines of the frustum until they intersect the center line at L. Divide the half plan E D F into a number of equal parts as shown; from these points erect lines intersecting the base line H I from which draw lines to the apex L. As the elbow is to be in two pieces, and the axis at right angles, draw the angle T R S,

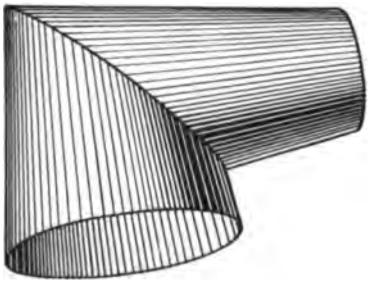

Fig. 53.

bisect it at U and draw the line R V. No matter what the angle of the elbow, use this method. Now establish the point J at some convenient point on the cone, and from J, parallel to R V, draw the miter line J K intersecting the radial lines drawn through the cone; from these points and at right angles to the center line A B draw lines intersecting the side of the cone J H from 1 to 7. If it is desired to know how the side of the tapering elbow would look, take a tracing of N O K J, reverse it and place it as shown by J W M K..

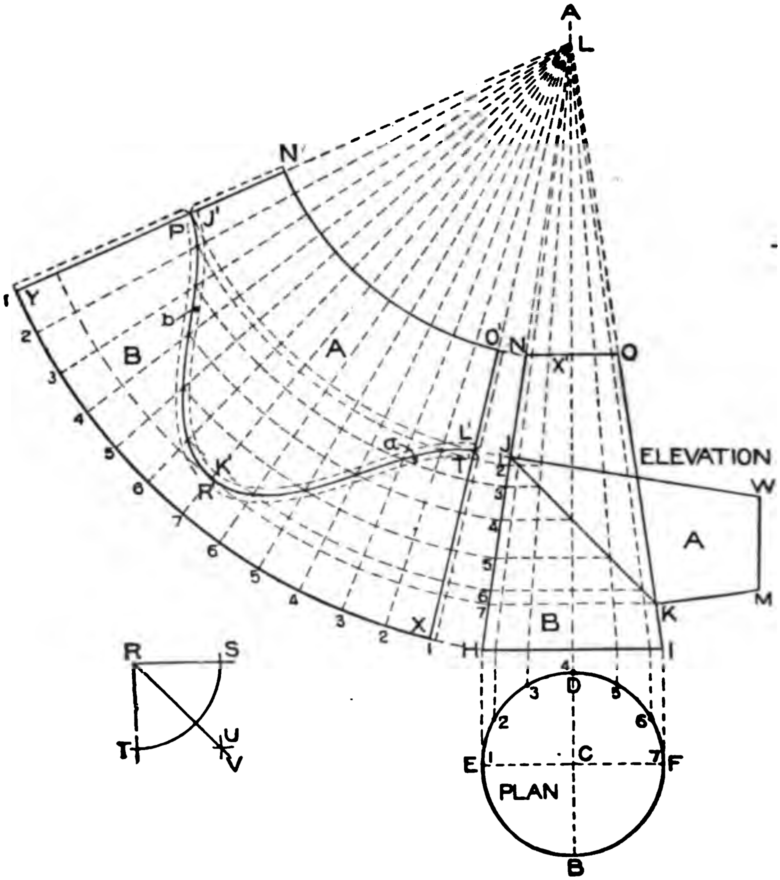

Fig. 54.

For the pattern proceed as follows: With L as a center and L H as a radius describe the arc 1 1. Starting from 1 set off on this arc twice the stretchout of 1 4 7 in plan, as shown by similar figures on 1 1, from which draw radial lines to the apex L. Again using L as center with radii equal to L N, L 1, L 2 to L 7, draw arcs as shown intersecting radial lines having similar numbers. Through these intersections draw the line J′ L′. Then O′ N′ J′ K′ L′ or A will be the pattern for the upper arm (A) in elevation, and P′ R′ T′ X Y or B the pattern for the lower arm (B) in elevation.

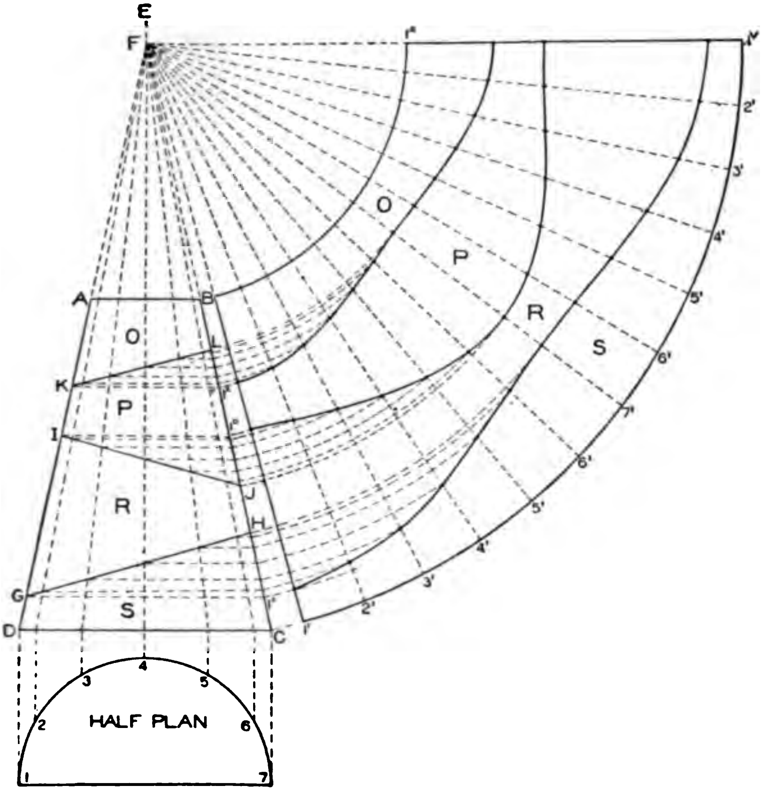

Fig. 55.

The pattern should be developed full size in practice and then pricked from the paper on to the sheet metal, drawing the two patterns as far apart as to admit allowing an edge to A at *a*; also an edge at *b* to B for seaming.

When a pattern is to contain more than two pieces the method of constructing the miter lines in the elevation of the cone is slightly different as shown in Fig. 55. Assume the bottom to be 3 inches in diameter and the top 1½ inches. Let the vertical height be 4 inches. In this problem, as in the preceding, the various pieces necessary to form the elbow are cut from one cone whose dimensions must be determined from the dimensions of the required elbow. The first step is to determine the miter lines, which can be done the same as if regular pieced elbows were being developed. As the elbow is to consist of four pieces in 90°, follow the rule given in connection with elbow drafting. The top and bottom piece equal 2; the two middle pieces equal 4; total 6. $\frac{90}{6} = 15$. Lay off A B C D according to the dimensions given, and draw the half plan below D C; divide it into equal parts as shown. From the points of division erect perpendiculars intersecting D C, from which draw lines meeting the center line E 4 at F.

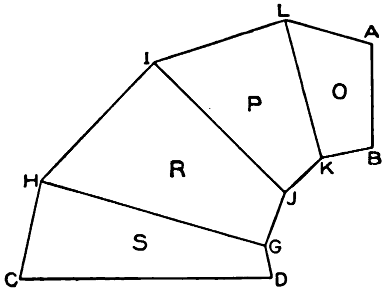

Fig. 56.

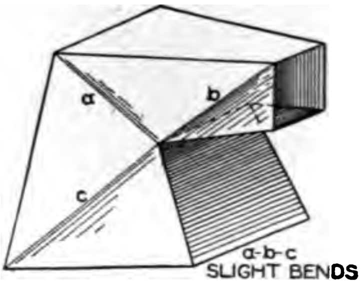

Fig. 57.

We assume that the amount of rise and projection of the elbow are not specified, excepting that the lines of axis will be at right angles. Knowing the angle of the miter line, it becomes a matter of judgment upon the part of the pattern draftsman, what length shall be given to each of the pieces composing the elbow. Therefore establish the points G, I and K, making D G, G I, I K and K A. ½, 1⅞, ¾ and 1 inch respectively. From G, I and K draw the horizontal lines G $1''$, I 1^{7} and K 1^{x}. To each of these lines draw the lines G H, I J and K L respectively at an angle of 15° intersecting the radial lines in the cone as shown. From these intersections draw horizontal lines cutting the side of the cone. Then using F as a center, obtain the various patterns O, P, R and S in the manner already explained.

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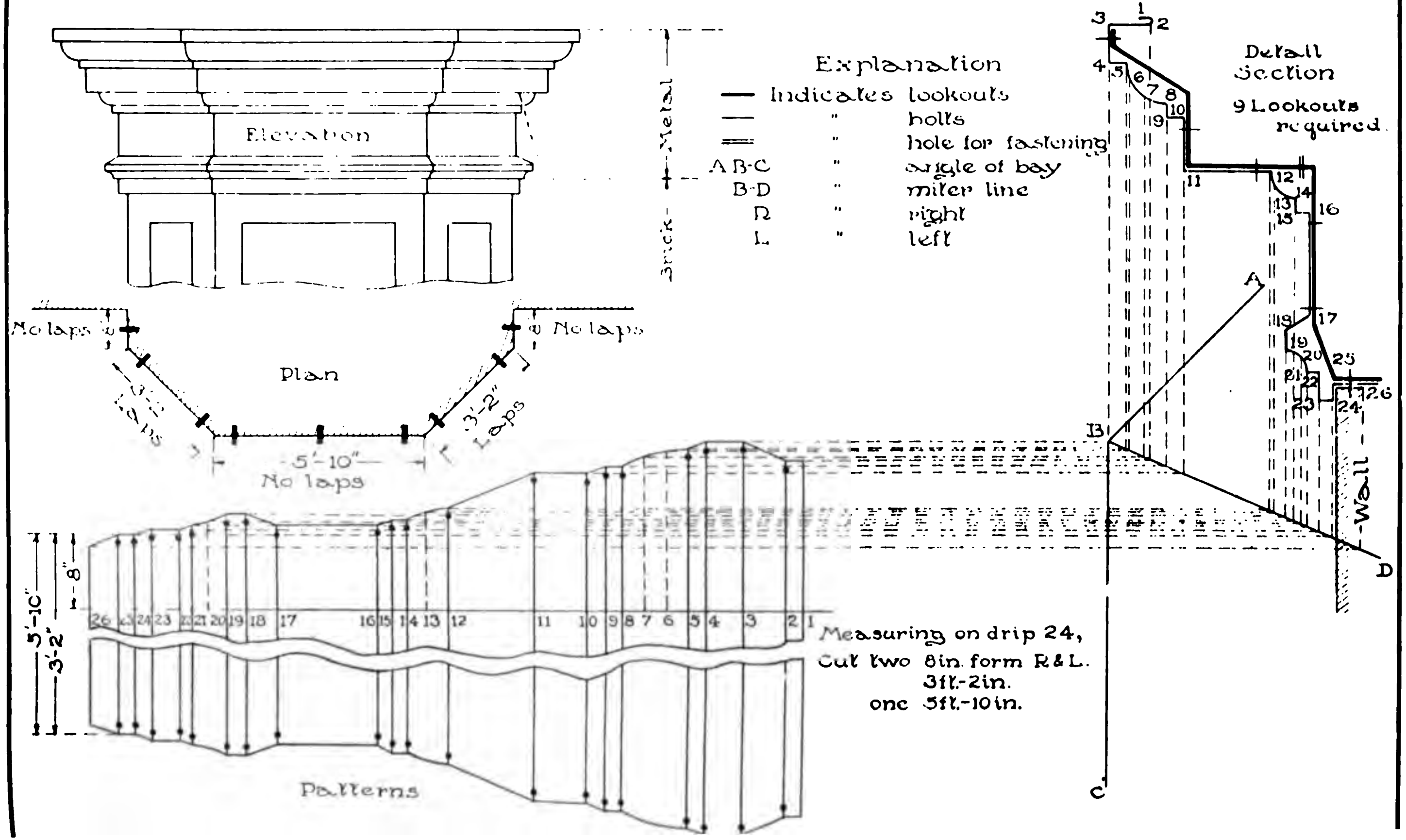
ASTOR, LENOX AND
TILDEN FOUNDATIONS

PATTERNS AND LAY-OUT FOR CORNICE OVER BRICK BAY



In Fig. 56 is shown a side view of the elbow, resulting from preceding operations; while it can be drawn from dimensions obtained in Fig. 55, it would be impossible to draw it without first having these dimensions.

In Fig. 57 is shown a perspective view of a tapering square elbow of square section in two pieces. This elbow may have any given taper. This problem will be developed by triangulation and parallel lines; it is an interesting study in projections as well as in developments. First draw the elevation of the elbow in Fig. 58 making 1–6 equal to $3\frac{1}{2}$ inches, the vertical height 1–2, $4\frac{1}{2}$ inches, and 6–5, $2\frac{1}{2}$ inches; the projection between 1 and 2 should be $\frac{5}{8}$ inch and between 5 and 6, $\frac{3}{8}$ inch. Make the horizontal distance from 5 to 4, 2 inches, and the rise at 4 from the horizontal line $\frac{1}{4}$ inch, and the vertical distance from 4 to 3, $1\frac{1}{4}$ inches. Then draw a line from 3 to 2 to complete the elevation.

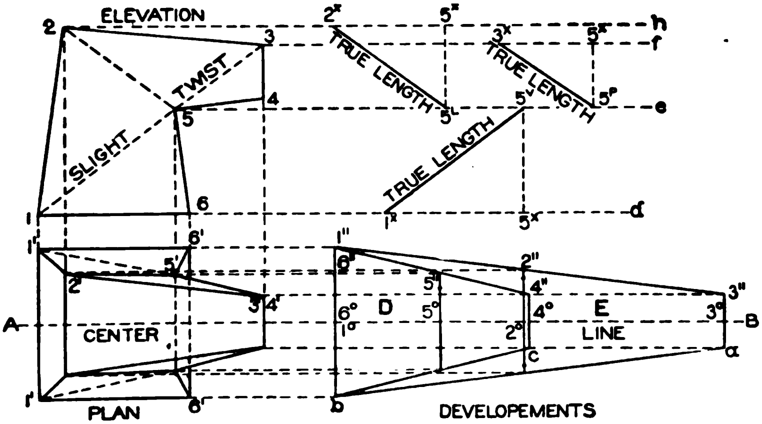


Fig. 58.

In its proper position below the line 1–6, draw the plan on that line, as shown by 1′ 1′ 6′ 6′. Through this line draw the center line A B. As the elbow should have a true taper from 1 to 3 and from 4 to 6, we may develop the patterns for the top and bottom pieces first and then from these construct the plan. Therefore, take the distances from 1 to 2 to 3 and from 4 to 5 to 6 in elevation and place them on the line A B in plan as shown respectively from 1° to 2° to 3° and from 4° to 5° to 6°; through these points draw vertical lines as shown. While the full developments

E and D are shown we shall deal with but one-half in the explanation which follows. As the elbow is to have the same taper on either side, take the half distance of the bottom of the elbow 1–6 and place it as shown from 1°–6° to 1″–6″, and the half width of the top of the elbow 3–4 and place it as shown from 3° to 3″ and 4° to 4″. Then draw lines from 3″ to 1″ intersecting the bend 2° at 2″, and a line from 4″ to 6″ intersecting the bend 5° at 5″. Trace these points on the opposite side of the line A B. Then 1″ 3″ *a b* will be the pattern for the top of the elbow and 6″ 4″ *c b* the pattern for the bottom. From these various points of intersection draw horizontal lines to the plan, and intersect them by lines drawn from similarly numbered points in the elevation at right angles to A B in plan. Draw lines through the points thus obtained in plan as shown by 1′, 2′, 3′, 4′, 5′ and 6′ which will represent the half plan view. For the completed plan, trace these lines opposite the line A B as shown. It will be noticed that the line 3–4 in elevation is perpendicular as shown by 3′ 4′ in plan while the points 2′ and 5′ project from it, showing that the piece 2–3–4–5 in elevation must be slightly twisted along the line 5–3 when forming the elbow. Similarly slight bends will be required along the lines 1–5 and 5–2.

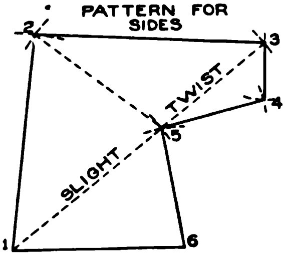


Fig. 59.

It will now be necessary to obtain the true lengths or a diagram of triangles on the lines 1–5, 5–2 and 5–3. Connect similar numbers in plan as shown from 1′ to 5′, 5′ to 2′ and 5′ to 3′, the last two lines being already shown. From similar points in elevation draw horizontal lines as shown by 2–*h*, 3–*f*, 5–*e* and 6–*d*. Take the distances from 1′ to 5′, 5′ to 2′ and 5′ to 3′ in plan and place them on one of the lines having a similar number in elevation, as shown respectively by 1^x 5^x, 5^x 2^x and 5^x 3^x. From the points marked 5^x draw vertical lines intersecting the horizontal line drawn from 5 at 5^v, 5^L and 5^P respectively. Now draw the true lengths 1^x 5^v, 2^x 5^L, and 3^x 5^P. For the pattern draw any line as 1–6 in Fig. 59 equal to 1–6 in Fig. 58. Now with 6″ 5″ in D as a radius and 6 in Fig. 59 as a center, describe the arc 5 which is intersected by an arc struck from 1 as a center and the true length

$1^x\ 5^v$ in Fig. 58 as radius. Then using the true length $5^L\ 2^x$ as radius and 5 in Fig. 59 as center, describe the arc 2, which is intersected by an arc struck from 1 as center and 1″ 2″ in E in Fig. 58 as radius. Using the true length $5^p\ 3^x$ as radius and 5 in Fig. 59 as center, describe the arc 3, and intersect it by an arc struck from 2 as center and 2″ 3″ in E in Fig. 58 as a radius. Now with 5″ 4″ in D as a radius and 5 in Fig. 59 as a center, describe the arc 4, and intersect it by an arc struck from 3 as center and 3–4 in the elevation in Fig. 58 as a radius. Draw lines from point to point in Fig. 59 to complete the pattern. Laps should be allowed on all patterns, for seaming. Slight bends will take place as shown on the pattern, also as is shown by *a b* and *c* in Fig. 57. If the joint is to be on the line 2–5 in elevation in Fig. 58, the necessary pieces can be joined together.

In Fig. 60 is shown a perspective view of a five-piece tapering elbow, having a round base and an elliptical top. This form is generally known as a *ship ventilator*. The principles shown in this problem are applicable to any form or shape no matter what the respective profiles may be at the base or top. The first step is to draw a correct side view of the elbow as shown in Fig. 61. The outline A B C D E F can be drawn at pleasure, but for practice, dimensions are given. First draw the vertical line A F equal to 4½ inches. On the same line extend measure down 1¼ inches to *f* and draw the horizontal line H B. From *f* set off a distance of 1¼ inches at G, and using G as a center and G F as a radius describe the arc F E intersecting H B at E, from which draw the vertical line E D equal to 1 inch. Draw D C equal to 1¾ inches, then draw C B. From B lay off 5¾ inches, and using this point (H) as a center and H B as a radius describe the arc B A. The portion shown B E D C is a straight piece of pipe whose section is shown by I J K L. Now divide the two arcs B A and E F into the same number of parts that the elbow is to have pieces (in this case four) and draw the lines of joint or miter lines as shown by U V, etc.

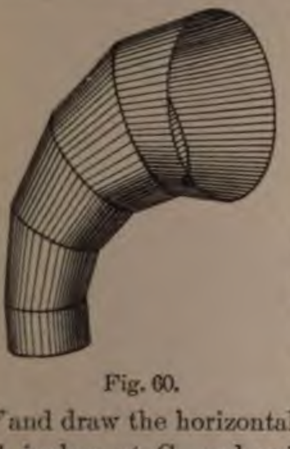


Fig. 60.

Bisect each one of the joint lines and obtain the points *a b c d* and *e*. Then A B C D E F will be the side view.

The patterns will be developed by triangulation, but before this can be done, true sections must be obtained on all of the lines in side elevation. The true sections on the lines B E and C D are shown by I J K L. The length of the sections are shown by the joint lines, but the width must be obtained from a front outline of the elbow, which is constructed as follows: In its proper relation to the side elevation, draw the center line M R upon which draw

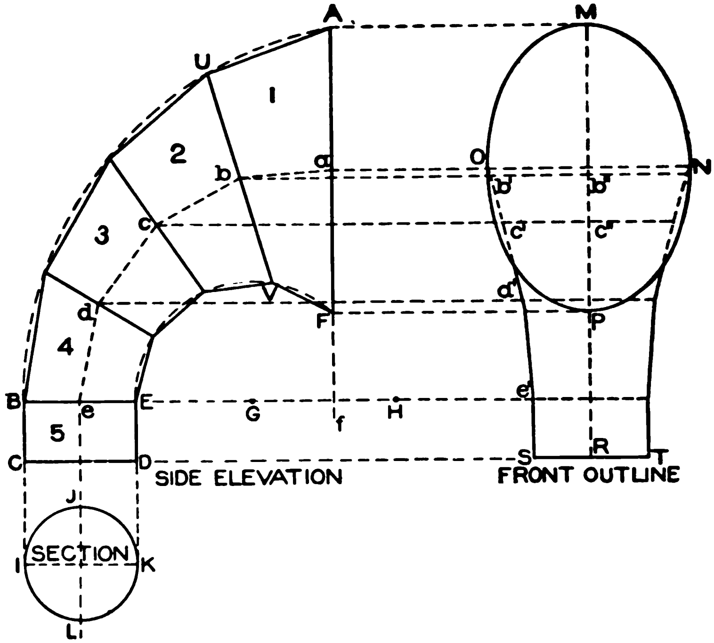


Fig. 61.

the ellipse M N O P (by methods already given in Mechanical Drawing) which represents the section on A F in side. Take half the diameter I K in section and place it on either side of the center line M R as R T or R S. Then draw the outline O S and T N in a convenient location. While this line is drawn at will, it should be understood that when once drawn, it becomes a fixed line. Now from the various intersections *a b c d* and *e* in the side elevation, draw lines through and intersecting the front outline as shown on one side by O, *b'*, *c'*, *d'* and *e'*. Then these distances will represent the widths of the sections shown by similar letters in side. For example, the method will be shown for obtaining the true section on U V, and the pattern for piece 1 in side elevation. To avoid a confusion of lines take a tracing of A F V U and place it as shown by 1, 13, 12, O in Fig. 62. On 1–13 place the half profile M N P of Fig. 61. Bisect O–12 in Fig. 62 and obtain the point 6; at a right angle to O–12 from 6 draw the line 6 6' equal to *b' b"* in front outline in Fig. 61. Then through the three points O, 6' and 12 in Fig. 62, draw the semi-ellipse, which will represent the half section on U V. The other sections on the joint lines in side elevation are obtained in the same manner.

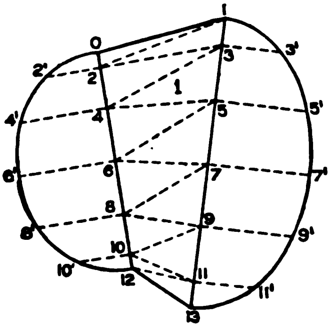


Fig. 62.

If the sections were required for piece 2 in side it would be necessary to use only O 6' 12 in Fig. 62 and place it on U V in Fig. 61, and on a perpendicular line erected from *c*, place the width *c' c"* shown in front and through the three points obtained again draw the semi-elliptical profile or section. Now divide the two half sections (Fig. 62) into equal parts as shown by the small figures, from which at right angles to 1–13 and O–12 draw lines intersecting these base lines from 1–13. Connect opposite points as 1 to 2 to 3 to 4 to 5, etc., to 12. Then these lines will represent

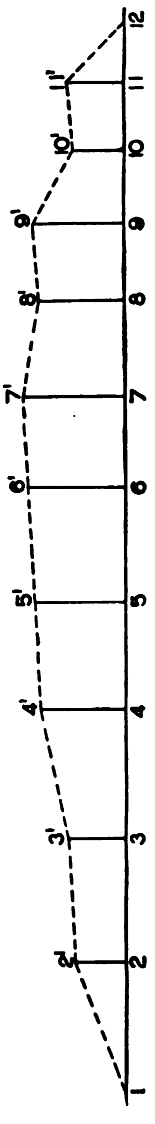


Fig. 63.

the bases of sections whose altitudes are equal to the heights in the half section. For these heights proceed as follows:

Take the various lengths from 1 to 2, 2 to 3, 3 to 4, 4 to 5, etc., to 11 to 12 and place them on the horizontal line in Fig. 63 as shown by similar figures; from these points erect vertical lines equal in height to similar figures, in the half section in Fig. 62 as shown by similar figures in Fig. 63. For example: Take the distance from 7 to 8 in Fig. 62 and place it as shown from 7 to 8 in Fig. 63 and erect vertical lines 7–7′, and 8–8′ equal to 7–7′ and 8–8′ in Fig. 62. Draw a line from 7′ to 8′ in Fig. 63 which is the true length on 7–8 in Fig. 62. For the pattern take the distance of 1–O and place it as shown by 1–O in Fig. 64. Now using O as a center and O 2′ in Fig. 62 as a radius, describe the arc 2 in Fig. 64 and intersect it by an arc struck from 1 as a center with 1–2′ in Fig. 63 as a radius. Now with 1–3′ in Fig. 62 as a radius and 1 in Fig. 64 as a center, describe the arc 3, and intersect it by an arc struck from 2 as center and 2′–3′ in Fig. 63 as a radius. Proceed thus, using alternately as radii, first the divisions in O–6′–12 in Fig. 62, then the proper line in Fig. 63, the divisions in 1–7′–13 in Fig. 62 and again the proper line in Fig. 63, until the line 12–13 in Fig. 64 is obtained, which equals 12–13 in Fig. 62. In this manner all of the sections are obtained, to which laps must be allowed for wiring and seaming.

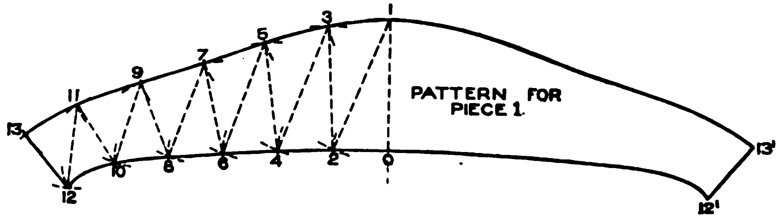


Fig. 64.

TABLES.

The following tables will be found convenient for the Sheet-Metal Worker:

TABLES	PAGE.
Weight of Cast Iron, Wrought Iron, Copper, Lead, Brass and Zinc	62
Sheet Copper	63
Sheet Zinc	64
Standard Gauge for Sheet Iron and Steel	65
Weights of Flat Rolled Iron	66–71
Square and Round Iron Bars	72-73
Angles and Tees	74

WEIGHT OF A SQUARE FOOT OF CAST AND WROUGHT IRON, COPPER, LEAD, BRASS AND ZINC.

FROM $\frac{1}{16}$ INCH TO ONE INCH IN THICKNESS.

THICKNESS.	CAST IRON.	WROUGHT IRON.	COPPER.	LEAD.	BRASS.	ZINC.
Inch.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1-16	2.346	2.517	2.89	3.691	2.675	2.34
1-8	4.693	5.035	5.781	7.382	5.35	4.68
3-16	7.039	7.552	8.672	11.074	8.025	7.02
1-4	9.386	10.07	11.562	14.765	10.7	9.36
5-16	11.733	12.588	14.453	18.456	13.375	11.7
3-8	14.079	15.106	17.344	22.148	16.05	14.04
7-16	16.426	17.623	20.234	25.839	18.725	16.34
1-2	18.773	20.141	23.125	29.53	21.4	18.72
9-16	21.119	22.659	26.016	33.222	24.075	
5-8	23.466	25.176	28.906	36.923	26.75	
11-16	25.812	27.694	31.797	40.604	29.425	
3-4	28.159	30.211	34.688	44.296	32.1	
13-16	30.505	32.729	37.578	47.987		
7-8	32.852	35.247	40.469	51.678		
15-16	35.199	37.764	43.359	55.37		
1	37.545	40.282	46.25	59.061		

NOTE.—The wrought iron and the copper weights are those of hard-rolled plates.

SHEET COPPER.

Official table adopted by the Association of Copper Manufacturers of the United States. Rolled copper has specific gravity of 8.93. One cubic foot weighs 558.125 pounds. One square foot, one inch thick, weighs 46.51 pounds.

Stubs' Gauge, (nearest number).	Thickness in decimal parts of an inch.	Ounces per sq. ft.	Sheets 14"x48" Weight in pounds.	Sheets 24"x 48" Weight in pounds.	Sheets 30"x 60" Weight in pounds.	Sheets 36"x 72" Weight in pounds.	Sheets 48"x 72" Weight in pounds.
35........	.00537	4	1.16	2	3.12	4.50	6
33........	.00806	6	1.75	3	4.68	6.75	9
31........	.0107	8	2.33	4	6.25	9	12
29........	.0134	10	2.91	5	7.81	11.25	15
27........	.0161	12	3.50	6	9.37	13.50	18
26........	.0188	14	4.08	7	10.93	15.75	21
24........	.0215	16	4.66	8	12.50	18	24
23........	.0242	18	5.25	9	14.06	20.25	27
22........	.0269	20	5.83	10	15.62	22.50	30
21........	.0322	24	7	12	18.75	27	36
19........	.0430	32	9.33	16	25	36	48
18........	.0538	40	11.66	20	31.25	45	60
16........	.0645	48	14	24	37.50	54	72
15........	.0754	56	16.33	28	43.75	63	84
14........	.0860	64	18.66	32	50	72	96
13........	.095	70	....	35	55	79	105
12........	.109	81	....	40½	63	91	122
11........	.120	89	....	44½	70	100	134
10........	.134	100	....	50	78	112	150
9........	.148	110	....	55	86	124	165
8........	.165	123	....	61	96	138	184
7........	.180	134	....	67	105	151	201
6........	.203	151	....	75½	118	170	227
5........	.220	164	....	82	128	184	246
4........	.238	177	....	88½	138	199	266
3........	.259	193	....	96	151	217	289
2........	.284	211	....	105⅓	165	238	317
1........	.300	223	....	111⅓	174	251	335
0........	.340	253	....	126½	198	285	380

SHEET ZINC.

Numbers		4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Weight per sq. foot		.30	.37	.45	.52	.60	.67	.75	.90	1.05	1.20	1.35	1.50	1.68	1.87	2.06	2.25	2.62	3.00	3.37
Approximate thickness in inches		.008	.010	.012	.014	.016	.018	.020	.024	.028	.032	.036	.040	.045	.050	.055	.060	.070	.080	.090
Size of sheet.	Sq. ft. per sheet.	APPROXIMATE WEIGHT PER SHEET.																		
24 x 84 in.	14.	4.2	5.2	6.3	7.3	8.4	9.4	10.5	12.6	14.7	16.8	18.9	21.	23.5	26.2	28.9	31.5	36.7	42.	47.2
26 x 84	15.2	4.6	5.6	6.9	7.9	9.1	10.2	11.4	13.7	16.	18.3	20.5	22.8	25.6	28.4	31.3	34.2	39.9	45.6	51.2
28 x 84	16.3	4.9	6.	7.4	8.5	9.8	10.9	12.2	14.7	17.1	19.6	22.	24.5	27.4	30.5	33.6	36.7	42.7	48.9	54.9
30 x 84	17.5	5.3	6.5	7.9	9.1	10.5	11.8	13.2	15.8	18.4	21.	23.6	26.2	29.4	32.8	36.1	39.4	45.8	52.5	59.
32 x 84	18.7	5.6	6.9	8.4	9.7	11.2	12.6	14.1	16.9	19.7	22.5	25.3	32.8	31.4	35.	38.5	42.	49.	56.1	63.
34 x 84	19.9	6.0	7.4	9.	10.4	12.	13.4	15.	18.	20.9	23.9	26.9	29.9	33.4	37.2	41.	44.8	52.2	59.7	67.
36 x 84	21.	6.3	7.8	9.5	10.9	12.6	14.1	15.8	18.9	22.	25.2	28.4	31.5	35.3	39.3	43.3	47.2	55.	63.	70.8
36 x 96	24.	7.2	8.9	10.8	12.5	14.4	16.1	18.	21.6	25.2	28.8	32.4	36.	40.3	44.9	49.5	54.	62.8	72.	80.9
36 x 108	27.	8.1	10.	12.2	14.1	16.2	18.1	20.3	24.3	28.4	32.4	36.5	40.5	45.4	50.5	55.6	60.7	70.7	81.	91.
40 x 84	23.4	7.	8.7	10.6	12.2	14.1	15.7	17.6	21.	24.6	28.1	31.6	35.1	39.3	43.8	48.2	52.6	61.3	70.2	78.8
40 x 96	26.8	8.	9.9	12.1	14.	16.1	18.	20.1	24.1	28.1	32.2	36.2	40.2	45.	50.1	55.2	60.3	70.2	80.4	90.3
44 x 84	25.7	7.7	9.5	11.6	13.4	15.4	17.2	19.3	23.1	27.	30.8	34.7	38.6	43.2	48.1	53.	57.8	67.4	77.1	86.6
46 x 90	28.7	8.6	10.6	12.9	14.9	17.2	19.2	21.5	25.8	30.1	34.4	38.7	43.	48.2	53.7	59.1	64.6	75.2	86.1	96.7
48 x 84	28.	8.4	10.4	12.6	14.6	16.8	18.8	21.	25.2	29.4	33.6	37.8	42.	47.	52.4	57.7	63.	73.4	84.	94.4
48 x 96	32.	9.6	11.9	14.4	16.7	19.2	21.5	24.	28.8	33.6	38.4	43.2	48.	53.8	59.9	65.9	72.	83.9	96.	107.8
50 x 108	37.5	11.3	13.9	16.9	19.5	22.5	25.1	28.2	33.8	39.3	45.	50.7	56.3	63.	70.1	77.3	84.4	98.3	112.5	126.4
52 x 84	30.4	9.1	11.3	13.7	15.8	18.3	20.4	22.8	27.4	31.9	36.5	41.	45.6	51.	56.9	62.6	68.4	79.6	91.2	102.5

Casks average about 600 pounds each. No. 4 to No. 17. Boxes average about 500 pounds. No. 18 and heavier.

UNITED STATES STANDARD GAUGE FOR SHEET AND PLATE IRON AND STEEL

COPY [Public—No. 137]

An act establishing a standard gauge for sheet and plate iron and steel.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That for the purpose of securing uniformity the following is established as the only standard gauge for sheet and plate iron and steel in the United States of America, namely:

Number of Gauge	THICKNESS		WEIGHT		Number of Gauge
	Approximate thickness in fractions of an inch	Approximate thickness in decimal parts of an inch	Weight per square foot in OUNCES avoirdupois	Weight per square foot in POUNDS avoirdupois	
0000000	1-2	.5	320	20.	0000000
000000	15-32	.46875	300	18.75	000000
00000	7-16	.4375	280	17.5	00000
0000	13-32	.40625	260	16.25	0000
000	3-8	.375	240	15.	000
00	11-32	.34375	220	13.75	00
0	5-16	.3125	200	12.5	0
1	9-32	.28125	180	11.25	1
2	17-64	.265625	170	10.625	2
3	1-4	.25	160	10.	3
4	15-64	.234375	150	9.375	4
5	7-32	.21875	140	8.75	5
6	13-64	.203125	130	8.125	6
7	3-16	.1875	120	7.5	7
8	11-64	.171875	110	6.875	8
9	5-32	.15625	100	6.25	9
10	9-64	.140625	90	5.625	10
11	1-8	.125	80	5.	11
12	7-64	.109375	70	4.375	12
13	3-32	.09375	60	3.75	13
14	5-64	.078125	50	3.125	14
15	9-128	.0703125	45	2.8125	15
16	1-16	.0625	40	2.5	16
17	9-160	.05625	36	2.25	17
18	1-20	.05	32	2.	18
19	7-160	.04375	28	1.75	19
20	3-80	.0375	24	1.5	20
21	11-320	.034375	22	1.375	21
22	1-32	.03125	20	1.25	22
23	9-320	.028125	18	1.125	23
24	1-40	.025	16	1.	24
25	7-320	.021875	14	.875	25
26	3-160	.01875	12	.75	26
27	11-640	.0171875	11	.6875	27
28	1-64	.015625	10	.625	28
29	9-640	.0140625	9	.5625	29
30	1-80	.0125	8	.5	30
31	7-640	.0109375	7	.4375	31
32	13-1280	.01015625	6½	.40625	32
33	3-320	.009375	6	.375	33
34	11-1280	.00859375	5½	.34375	34
35	5-640	.0078125	5	.3125	35
36	9-1280	.00703125	4½	.28125	36
37	17-2560	.0066406	4¼	.265625	37
38	1-160	.00625	4	.25	38

And on and after July first, eighteen hundred and ninety-three, the same and no other shall be used in determining duties and taxes levied by the United States of America on sheet and plate iron and steel. But this act shall not be construed to increase duties upon any articles which may be imported.

SEC. 2. That the Secretary of the Treasury is authorized and required to prepare suitable standards in accordance herewith.

SEC. 3. That in the practical use and application of the standard gauge hereby established a variation of two and one-half per cent either way may be allowed.

Approved, March 3, 1893.

WEIGHTS OF FLAT ROLLED IRON PER LINEAR FOOT.

Iron weighing 480 pounds per cubic foot.

Thickness in Inches.	1″	1¼″	1½″	1¾″	2″	2¼″	2½″	2¾″	12″
1/16	.208	260	.313	.365	.417	.469	.521	.573	2.50
1/8	.417	.521	.625	.729	.833	.938	1.04	1.15	5.00
3/16	.625	.781	.938	1.09	1.25	1.41	1.56	1.72	7.50
1/4	.833	1.04	1.25	1.46	1.67	1.88	2.08	2.29	10.00
5/16	1.04	1.30	1.56	1.82	2.08	2.34	2.60	2.86	12.50
3/8	1.25	1.56	1.88	2.19	2.50	2.81	3.13	3.44	15.00
7/16	1.46	1.82	2.19	2.55	2.92	3.28	3.65	4.01	17.50
1/2	1.67	2.08	2.50	2.92	3.33	3.75	4.17	4.58	20.00
9/16	1.88	2.34	2.81	3.28	3.75	4.22	4.69	5.16	22.50
5/8	2.08	2.60	3.13	3.65	4.17	4.69	5.21	5.73	25.00
11/16	2.29	2.86	3.44	4.01	4.58	5.16	5.73	6.30	27.50
3/4	2.50	3.13	3.75	4.38	5.00	5.63	6.25	6.88	30.00
13/16	2.71	3.39	4.06	4.74	5.42	6.09	6.77	7.45	32.50
7/8	2.92	3.65	4.38	5.10	5.83	6.56	7.29	8.02	35.00
15/16	3.13	3.91	4.69	5.47	6.25	7.03	7.81	8.59	37.50
1	3.33	4.17	5.00	5.83	6.67	7.50	8.33	9.17	40.00
1 1/16	3.54	4.43	5.31	6.20	7.08	7.97	8.85	9.74	42.50
1 1/8	3.75	4.69	5.63	6.56	7.50	8.44	9.38	10.31	45.00
1 3/16	3.96	4.95	5.94	6.93	7.92	8.91	9.90	10.89	47.50
1 1/4	4.17	5.21	6.25	7.29	8.33	9.38	10.42	11.46	50.00
1 5/16	4.37	5.47	6.56	7.66	8.75	9.84	10.94	12.03	52.50
1 3/8	4.58	5.73	6.88	8.02	9.17	10.31	11.46	12.60	55.00
1 7/16	4.79	5.99	7.19	8.39	9.58	10.78	11.98	13.18	57.50
1 1/2	5.00	6.25	7.50	8.75	10.00	11.25	12.50	13.75	60.00
1 9/16	5.21	6.51	7.81	9.11	10.42	11.72	13.02	14.32	62.50
1 5/8	5.42	6.77	8.13	9.48	10.83	12.19	13.54	14.90	65.00
1 11/16	5.63	7.03	8.44	9.84	11.25	12.66	14.06	15.47	67.50
1 3/4	5.83	7.29	8.75	10.21	11.67	13.13	14.58	16.04	70.00
1 13/16	6.04	7.55	9.06	10.57	12.08	13.59	15.10	16.61	72.50
1 7/8	6.25	7.81	9.38	10.94	12.50	14.06	15.63	17.19	75.00
1 15/16	6.46	8.07	9.69	11.30	12.92	14.53	16.15	17.76	77.50
2	6.67	8.33	10.00	11.67	13.33	15.00	16.67	18.33	80.00

WEIGHTS OF FLAT ROLLED IRON PER LINEAR FOOT.

(Continued)

Thickness in Inches.	3"	3¼"	3½"	3¾"	4"	4¼"	4½"	4¾"	12"
$\frac{1}{16}$	.625	.677	.729	.781	.833	.885	.938	.990	2.50
$\frac{1}{8}$	1.25	1.35	1.46	1.56	1.67	1.77	1.88	1.98	5.00
$\frac{3}{16}$	1.88	2.03	2.19	2.34	2.50	2.66	2.81	2.97	7.50
$\frac{1}{4}$	2.50	2.71	2.92	3.13	3.33	3.54	3.75	3.96	10.00
$\frac{5}{16}$	3.13	3.39	3.65	3.91	4.17	4.43	4.69	4.95	12.50
$\frac{3}{8}$	3.75	4.06	4.38	4.69	5.00	5.31	5.63	5.94	15.00
$\frac{7}{16}$	4.38	4.74	5.10	5.47	5.83	6.20	6.56	6.93	17.50
$\frac{1}{2}$	5.00	5.42	5.83	6.25	6.67	7.08	7.50	7.92	20.00
$\frac{9}{16}$	5.63	6.09	6.56	7.03	7.50	7.97	8.44	8.91	22.50
$\frac{5}{8}$	6.25	6.77	7.29	7.81	8.33	8.85	9.38	9.90	25.00
$\frac{11}{16}$	6.88	7.45	8.02	8.59	9.17	9.74	10.31	10.89	27.50
$\frac{3}{4}$	7.50	8.13	8.75	9.38	10.00	10.63	11.25	11.88	30.00
$\frac{13}{16}$	8.13	8.80	9.48	10.16	10.83	11.51	12.19	12.86	32.50
$\frac{7}{8}$	8.75	9.48	10.21	10.94	11.67	12.40	13.13	13.85	35.00
$\frac{15}{16}$	9.38	10.16	10.94	11.72	12.50	13.28	14.06	14.84	37.50
1	10.00	10.83	11.67	12.50	13.33	14.17	15.00	15.83	40.00
$1\frac{1}{16}$	10.63	11.51	12.40	13.28	14.17	15.05	15.94	16.82	42.50
$1\frac{1}{8}$	11.25	12.19	13.13	14.06	15.00	15.94	16.88	17.81	45.00
$1\frac{3}{16}$	11.88	12.86	13.85	14.84	15.83	16.82	17.81	18.80	47.50
$1\frac{1}{4}$	12.50	13.54	14.58	15.63	16.67	17.71	18.75	19.79	50.00
$1\frac{5}{16}$	13.13	14.22	15.31	16.41	17.50	18.59	19.69	20.78	52.50
$1\frac{3}{8}$	13.75	14.90	16.04	17.19	18.33	19.48	20.63	21.77	55.00
$1\frac{7}{16}$	14.38	15.57	16.77	17.97	19.17	20.36	21.56	22.76	57.50
$1\frac{1}{2}$	15.00	16.25	17.50	18.75	20.00	21.25	22.50	23.75	60.00
$1\frac{9}{16}$	15.63	16.93	18.23	19.53	20.83	22.14	23.44	24.74	62.50
$1\frac{5}{8}$	16.25	17.60	18.96	20.31	21.67	23.02	24.38	25.73	65.00
$1\frac{11}{16}$	16.88	18.28	19.69	21.09	22.50	23.91	25.31	26.72	67.50
$1\frac{3}{4}$	17.50	18.96	20.42	21.88	23.33	24.79	26.25	27.71	70.00
$1\frac{13}{16}$	18.13	19.64	21.15	22.66	24.17	25.68	27.19	28.70	72.50
$1\frac{7}{8}$	18.75	20.31	21.88	23.44	25.00	26.56	28.13	29.69	75.00
$1\frac{15}{16}$	19.38	20.99	22.60	24.22	25.83	27.45	29.06	30.68	77.50
2	20.00	21.67	23.33	25.00	26.67	28.33	30.00	31.67	80.00

WEIGHTS OF FLAT ROLLED IRON PER LINEAR FOOT.

(Continued)

Thickness in Inches.	5"	5¼"	5½"	5¾"	6"	6¼"	6½"	6¾"	12"
1/16	1.04	1.09	1.15	1.20	1.25	1.30	1.35	1.41	2.50
1/8	2.08	2.19	2.29	2.40	2.50	2.60	2.71	2.81	5.00
3/16	3.13	3.28	3.44	3.59	3.75	3.91	4.06	4.22	7.50
1/4	4.17	4.38	4.58	4.79	5.00	5.21	5.42	5.63	10.00
5/16	5.21	5.47	5.73	5.99	6.25	6.51	6.77	7.03	12.50
3/8	6.25	6.56	6.88	7.19	7.50	7.81	8.13	8.44	15.00
7/16	7.29	7.66	8.02	8.39	8.75	9.11	9.48	9.84	17.50
1/2	8.33	8.75	9.17	9.58	10.00	10.42	10.83	11.25	20.00
9/16	9.38	9.84	10.31	10.78	11.25	11.72	12.19	12.66	22.50
5/8	10.42	10.94	11.46	11.98	12.50	13.02	13.54	14.06	25.00
11/16	11.46	12.03	12.60	13.18	13.75	14.32	14.90	15.47	27.50
3/4	12.50	13.13	13.75	14.38	15,00	15.63	16.25	16.88	30.00
13/16	13.54	14.22	14.90	15.57	16.25	16.93	17.60	18.28	32.50
7/8	14.58	15.31	16.04	16.77	17.50	18.23	18.96	19.69	35.00
15/16	15.63	16.41	17.19	17.97	18.75	19.53	20.31	21.09	37.50
1	16.67	17.50	18.33	19.17	20.00	20.83	21.67	22.50	40.00
1 1/16	17.71	18.59	19.48	20.36	21.25	22.14	23.02	23.91	42.50
1 1/8	18.75	19.69	20.63	21.56	22.50	23.44	24.38	25.31	45.00
1 3/16	19.79	20.78	21.77	22.76	23.75	24.74	25.73	26.72	47.50
1 1/4	20.83	21.88	22.92	23.96	25.00	26.04	27.08	28.13	50.00
1 5/16	21.88	22.97	24.06	25.16	26.25	27.34	28.44	29.53	52.50
1 3/8	22.92	24.06	25.21	26.35	27.50	28.65	29.79	30.94	55.00
1 7/16	23.96	25.16	26.35	27.55	28.75	29.95	31.15	32.34	57.50
1 1/2	25.00	26.25	27.50	28.75	30.00	31.25	32.50	33.75	60.00
1 9/16	26.04	27.34	28.65	29.95	31.25	32.55	33.85	35.16	62.50
1 5/8	27.08	28.44	29.79	31.15	32.50	33.85	35.21	36.56	65.00
1 11/16	28.13	29.53	30.94	32.34	33.75	35.16	36.56	37.97	67.50
1 3/4	29.17	30.63	32.08	33.54	35.00	36.46	37.92	39.38	70.00
1 13/16	30.21	31.72	33.23	34.74	36.25	37.76	39.27	40.78	72.50
1 7/8	31.25	32.81	34.38	35.94	37.50	39.06	40.63	42.19	75.00
1 15/16	32.29	33.91	35.52	37.14	38.75	40.36	41.98	43.59	77.50
2	33.33	35.00	36.67	38.33	40.00	41.67	43.33	45.00	80.00

WEIGHTS OF FLAT ROLLED IRON PER LINEAR FOOT.

(Continued)

Thickness in Inches	7″	7¼″	7½″	7¾″	8″	8¼″	8½″	8¾″	12″
$\frac{1}{16}$	1.46	1.51	1.56	1.61	1.67	1.72	1.77	1.82	2.50
$\frac{1}{8}$	2.92	3.02	3.13	3.23	3.33	3.44	3.54	3.65	5.00
$\frac{3}{16}$	4.38	4.53	4.69	4.84	5.00	5.16	5.31	5.47	7.50
$\frac{1}{4}$	5.83	6.04	6.25	6.46	6.67	6.88	7.08	7.29	10.00
$\frac{5}{16}$	7.29	7.55	7.81	8.07	8.33	8.59	8.85	9.11	12.50
$\frac{3}{8}$	8.75	9.06	9.38	9.69	10.00	10.31	10.63	10.94	15.00
$\frac{7}{16}$	10.21	10.57	10.94	11.30	11.67	12.03	12.40	12.76	17.50
$\frac{1}{2}$	11.67	12.08	12.50	12.92	13.33	13.75	14.17	14.58	20.00
$\frac{9}{16}$	13.13	13.59	14.06	14.53	15.00	15.47	15.94	16.41	22.50
$\frac{5}{8}$	14.58	15.10	15.63	16.15	16.67	17.19	17.71	18.23	25.00
$\frac{11}{16}$	16.04	16.61	17.19	17.76	18.33	18.91	19.48	20.05	27.50
$\frac{3}{4}$	17.50	18.13	18.75	19.38	20.00	20.63	21.25	21.88	30.00
$\frac{13}{16}$	18.96	19.64	20.31	20.99	21.67	22.34	23.02	23.70	32.50
$\frac{7}{8}$	20.42	21.15	21.88	22.60	23.33	24.06	24.79	25.52	35.00
$\frac{15}{16}$	21.88	22.66	23.44	24.22	25.00	25.78	26.56	27.34	37.50
1	23.33	24.17	25.00	25.83	26.67	27.50	28.33	29.17	40.00
$1\frac{1}{16}$	24.79	25.68	26.56	27.45	28.33	29.22	30.10	30.99	42.50
$1\frac{1}{8}$	26.25	27.19	28.13	29.06	30.00	30.94	31.88	32.81	45.00
$1\frac{3}{16}$	27.71	28.70	29.69	30.68	31.67	32.66	33.65	34.64	47.50
$1\frac{1}{4}$	29.17	30.21	31.25	32.29	33.33	34.38	35.42	36.46	50.00
$1\frac{5}{16}$	30.62	31.72	32.81	33.91	35.00	36.09	37.19	38.28	52.50
$1\frac{3}{8}$	32.08	33.23	34.38	35.52	36.67	37.81	38.96	40.10	55.00
$1\frac{7}{16}$	33.54	34.74	35.94	37.14	38.33	39.53	40.73	41.93	57.50
$1\frac{1}{2}$	35.00	36.25	37.50	38.75	40.00	41.25	42.50	43.75	60.00
$1\frac{9}{16}$	36.46	37.76	39.06	40.36	41.67	42.97	44.27	45.57	62.50
$1\frac{5}{8}$	37.92	39.27	40.63	41.98	43.33	44.69	46.04	47.40	65.00
$1\frac{11}{16}$	39.38	40.78	42.19	43.59	45.00	46.41	47.81	49.22	67.50
$1\frac{3}{4}$	40.83	42.29	43.75	45.21	46.67	48.13	49.58	51.04	70.00
$1\frac{13}{16}$	42.29	43.80	45.31	46.82	48.33	49.84	51.35	52.86	72.50
$1\frac{7}{8}$	43.75	45.31	46.88	48.44	50.00	51.56	53.13	54.69	75.00
$1\frac{15}{16}$	45.21	46.82	48.44	50.05	51.67	53.28	54.90	56.51	77.50
2	46.67	48.33	50.00	51.67	53.33	55.00	56.67	58.33	80.00

WEIGHTS OF FLAT ROLLED IRON PER LINEAR FOOT.

(Continued)

Thickness in Inches.	9″	9¼″	9½″	9¾″	10″	10¼″	10½″	10¾″	12″
1/16	1.88	1.93	1.98	2.03	2.08	2.14	2.19	2.24	2.50
1/8	3.75	3.85	3.96	4.06	4.17	4.27	4.38	4.48	5.00
3/16	5.63	5.78	5.94	6.09	6.25	6.41	6.56	6.72	7.50
1/4	7.50	7.71	7.92	8.13	8.33	8.54	8.75	8.96	10.00
5/16	9.38	9.64	9.90	10.16	10.42	10.68	10.94	11.20	12.50
3/8	11.25	11.56	11.88	12.19	12.50	12.81	13.13	13.44	15.00
7/16	13.13	13.49	13.85	14.22	14.58	14.95	15.31	15.68	17.50
1/2	15.00	15.42	15.83	16.25	16.67	17.08	17.50	17.92	20.00
9/16	16.88	17.34	17.81	18.28	18.75	19.22	19.69	20.16	22.50
5/8	18.75	19.27	19.79	20.31	20.83	21.35	21.88	22.40	25.00
11/16	20.63	21.20	21.77	22.34	22.92	23.49	24.06	24.64	27.50
3/4	22.50	23.13	23.75	24.38	25.00	25.62	26.25	26.88	30.00
13/16	24.38	25.05	25.73	26.41	27.08	27.76	28.44	29.11	32.50
7/8	26.25	26.98	27.71	28.44	29.17	29.90	30.63	31.35	35.00
15/16	28.13	28.91	29.69	30.47	31.25	32.03	32.81	33.59	37.50
1	30.00	30.83	31.67	32.50	33.33	34.17	35.00	35.83	40.00
1 1/16	31.88	32.76	33.65	34.53	35.42	36.30	37.19	38.07	42.50
1 1/8	33.75	34.69	35.63	36.56	37.50	38.44	39.38	40.31	45.00
1 3/16	35.63	36.61	37.60	38.59	39.58	40.57	41.56	42.55	47.50
1 1/4	37.50	38.54	39.58	40.63	41.67	42.71	43.75	44.79	50.00
1 5/16	39.38	40.47	41.56	42.66	43.75	44.84	45.94	47.03	52.50
1 3/8	41.25	42.40	43.54	44.69	45.83	46.98	48.13	49.27	55.00
1 7/16	43.13	44.32	45.52	46.72	47.92	49.11	50.31	51.51	57.50
1 1/2	45.00	46.25	47.50	48.75	50.00	51.25	52.50	53.75	60.00
1 9/16	46.88	48.18	49.48	50.78	52.08	53.39	54.69	55.99	62.50
1 5/8	48.75	50.10	51.46	52.81	54.17	55.52	56.88	58.23	65.00
1 11/16	50.63	52.03	53.44	54.84	56.25	57.66	59.06	60.47	67.50
1 3/4	52.50	53.96	55.42	56.88	58.33	59.79	61.25	62.71	70.00
1 13/16	54.38	55.89	57.40	58.91	60.42	61.93	63.44	64.95	72.50
1 7/8	56.25	57.81	59.38	60.94	62.50	64.06	65.63	67.19	75.00
1 15/16	58.13	59.74	61.35	62.97	64.58	66.20	67.81	69.43	77.50
2	60.00	61.67	63.33	65.00	66.67	68.33	70.00	71.67	80.00

WEIGHTS OF FLAT ROLLED IRON PER LINEAR FOOT.

(Concluded)

Thickness in Inches.	11"	11¼"	11½"	11¾"	12"	12¼"	12½"	12¾"
1/16	2.29	2.34	2.40	2.45	2.50	2.55	2.60	2.66
⅛	4.58	4.69	4.79	4.90	5.00	5.10	5.21	5.31
3/16	6.88	7.03	7.19	7.34	7.50	7.66	7.81	7.97
¼	9.17	9.38	9.58	9.79	10.00	10.21	10.42	10.63
5/16	11.46	11.72	11.98	12.24	12.50	12.76	13.02	13.28
⅜	13.75	14.06	14.38	14.69	15.00	15.31	15.63	15.94
7/16	16.04	16.41	16.77	17.14	17.50	17.86	18.23	18.59
½	18.33	18.75	19.17	19.58	20.00	20.42	20.83	21.25
9/16	20.63	21.09	21.56	22.03	22.50	22.97	23.44	23.91
⅝	22.92	23.44	23.96	24.48	25.00	25.52	26.04	26.56
11/16	25.21	25.78	26.35	26.93	27.50	28.07	28.65	29.22
¾	27.50	28.13	28.75	29.38	30.00	30.63	31.25	31.88
13/16	29.79	30.47	31.15	31.82	32.50	33.18	33.85	34.53
⅞	32.08	32.81	33.54	34.27	35.00	35.73	36.46	37.19
15/16	34.38	35.16	35.94	36.72	37.50	38.28	39.06	39.84
1	36.67	37.50	38.33	39.17	40.00	40.83	41.67	42.50
1 1/16	38.96	39.84	40.73	41.61	42.50	43.39	44.27	45.16
1 ⅛	41.25	42.19	43.13	44.06	45.00	45.94	46.88	47.81
1 3/16	43.54	44.53	45.52	46.51	47.50	48.49	49.48	50.47
1 ¼	45.83	46.88	47.92	48.96	50.00	51.04	52.08	53.13
1 5/16	48.13	49.22	50.31	51.41	52.50	53.59	54.69	55.78
1 ⅜	50.42	51.56	52.71	53.85	55.00	56.15	57.29	58.44
1 7/16	52.71	53.91	55.10	56.30	57.50	58.70	59.90	61.09
1 ½	55.00	56.25	57.50	58.75	60.00	61.25	62.50	63.75
1 9/16	57.29	58.59	59.90	61.20	62.50	63.80	65.10	66.41
1 ⅝	59.58	60.94	62.29	63.65	65.00	66.35	67.71	69.06
1 11/16	61.88	63.28	64.69	66.09	67.50	68.91	70.31	71.72
1 ¾	64.17	65.63	67.08	68.54	70.00	71.46	72.92	74.38
1 13/16	66.46	67.97	69.48	70.99	72.50	74.01	75.52	77.03
1 ⅞	68.75	70.31	71.88	73.44	75.00	76.56	78.13	79.69
1 15/16	71.04	72.66	74.27	75.89	77.50	79.11	80.73	82.34
2	73.33	75.00	76.67	78.33	80.00	81.67	83.33	85.00

The weights for 12" width are repeated on each page to facilitate making the additions necessary for plates wider than 12". Thus, to find the weight of 15¼" x ⅞", add the weights to be found in the same line for 3¼" x ⅞" and 12" x ⅞" = 9.48 + 35.00 = 44.48 lbs.

SQUARE AND ROUND IRON BARS.

Thickness or Diameter in Inches.	Weight of □ Bar One Foot long.	Weight of ○ Bar One Foot long.	Area of □ Bar in sq. inches.	Area of ○ Bar in sq. inches.	Circumference of ○ Bar in inches.
0					
1/16	.013	.010	.0039	.0031	.1963
1/8	.052	.041	.0156	.0123	.3927
3/16	.117	.092	.0352	.0276	.5890
1/4	.208	.164	.0625	.0491	.7854
5/16	.326	.256	.0977	.0767	.9817
3/8	.469	.368	.1406	.1104	1.1781
7/16	.638	.501	.1914	.1503	1.3744
1/2	.833	.654	.2500	.1963	1.5708
9/16	1.055	.828	.3164	.2485	1.7671
5/8	1.302	1.023	.3906	.3068	1.9635
11/16	1.576	1.237	.4727	.3712	2.1598
3/4	1.875	1.473	.5625	.4418	2.3562
13/16	2.201	1.728	.6602	.5185	2.5525
7/8	2.552	2.004	.7656	.6013	2.7489
15/16	2.930	2.301	.8789	.6903	2.9452
1	3.333	2.618	1.0000	.7854	3.1416
1/16	3.763	2.955	1.1289	.8866	3.3379
1/8	4.219	3.313	1.2656	.9940	3.5343
3/16	4.701	3.692	1.4102	1.1075	3.7306
1/4	5.208	4.091	1.5625	1.2272	3.9270
5/16	5.742	4.510	1.7227	1.3530	4.1233
3/8	6.302	4.950	1.8906	1.4849	4.3197
7/16	6.888	5.410	2.0664	1.6230	4.5160
1/2	7.500	5.890	2.2500	1.7671	4.7124
9/16	8.138	6.392	2.4414	1.9175	4.9087
5/8	8.802	6.913	2.6406	2.0739	5.1051
11/16	9.492	7.455	2.8477	2.2365	5.3014
3/4	10.21	8.018	3.0625	2.4053	5.4978
13/16	10.95	8.601	3.2852	2.5802	5.6941
7/8	11.72	9.204	3.5156	2.7612	5.8905
15/16	12.51	9.828	3.7539	2.9483	6.0868
2	13.33	10.47	4.0000	3.1416	6.2832
1/16	14.18	11.14	4.2539	3.3410	6.4795
1/8	15.05	11.82	4.5156	3.5466	6.6759
3/16	15.95	12.53	4.7852	3.7583	6.8722
1/4	16.88	13.25	5.0625	3.9761	7.0686
5/16	17.83	14.00	5.3477	4.2000	7.2649
3/8	18.80	14.77	5.6406	4.4301	7.4613
7/16	19.80	15.55	5.9414	4.6664	7.6576
1/2	20.83	16.36	6.2500	4.9087	7.8540
9/16	21.89	17.19	6.5664	5.1572	8.0503
5/8	22.97	18.04	6.8906	5.4119	8.2467
11/16	24.08	18.91	7.2227	5.6727	8.4430

SQUARE AND ROUND IRON BARS.

(Concluded)

Thickness or Diameter in Inches.	Weight of □ Bar One Foot long.	Weight of ○ Bar One Foot long.	Area of □ Bar in sq. inches.	Area of ○ Bar in sq. inches.	Circumference of ○ Bar in inches.
¾	25.21	19.80	7.5625	5.9396	8.6394
13/16	26.37	20.71	7.9102	6.2126	8.8357
⅞	27.55	21.64	8.2656	6.4918	9.0321
15/16	28.76	22.59	8.6289	6.7771	9.2284
3	30.00	23.56	9.0000	7.0686	9.4248
1/16	31.28	24.55	9.3789	7.3662	9.6211
⅛	32.55	25.57	9.7656	7.6699	9.8175
3/16	33.87	26.60	10.160	7.9798	10.014
¼	35.21	27.65	10.563	8.2958	10.210
5/16	36.58	28.73	10.973	8.6179	10.407
⅜	37.97	29.82	11.391	8.9462	10.603
7/16	39.39	30.94	11.816	9.2806	10.799
½	40.83	32.07	12.250	9.6211	10.996
9/16	42.30	33.23	12.691	9.9678	11.192
⅝	43.80	34.40	13.141	10.321	11.388
11/16	45.33	35.60	13.598	10.680	11.585
¾	46.88	36.82	14.063	11.045	11.781
13/16	48.45	38.05	14.535	11.416	11.977
⅞	50.05	39.31	15.016	11.793	12.174
15/16	51.68	40.59	15.504	12.177	12.370
4	53.33	41.89	16.000	12.566	12.566
1/16	55.01	43.21	16.504	12.962	12.763
⅛	56.72	44.55	17.016	13.364	12.959
3/16	58.45	45.91	17.535	13.772	13.155
¼	60.21	47.29	18.063	14.186	13.352
5/16	61.99	48.69	18.598	14.607	13.548
⅜	63.80	50.11	19.141	15.033	13.744
7/16	65.64	51.55	19.691	15.466	13.941
½	67.50	53.01	20.250	15.904	14.137
9/16	69.39	54.50	20.816	16.349	14.334
⅝	71.30	56.00	21.391	16.800	14.530
11/16	73.24	57.52	21.973	17.257	14.726
¾	75.21	59.07	22.563	17.721	14.923
13/16	77.20	60.63	23.160	18.190	15.119
⅞	79.22	62.22	23.766	18.665	15.315
15/16	81.26	63.82	24.379	19.147	15.512
5	83.33	65.45	25.000	19.635	15.708

ANGLE IRON.

Weight Per Linear Foot.

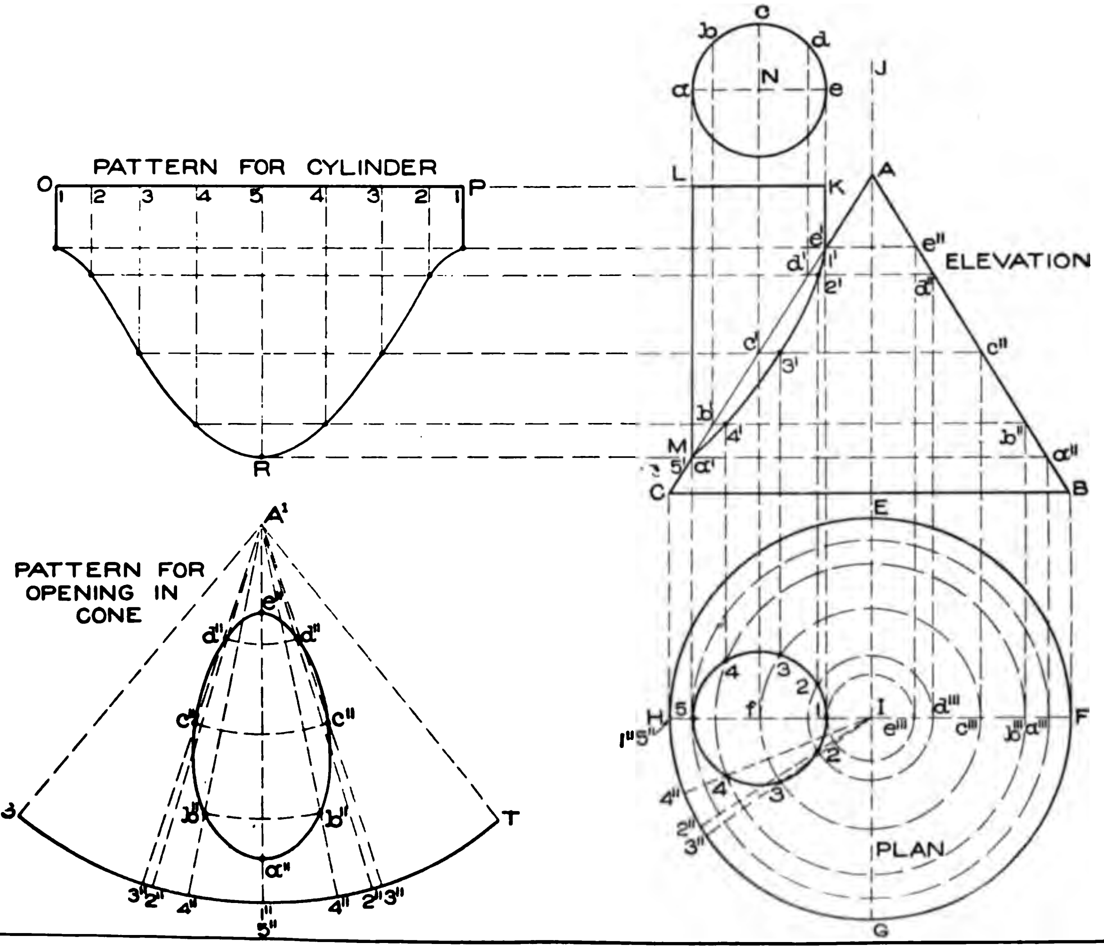
6 x 6 x ⅝	24	Lbs.	2 x 2 x ¼	3½	Lbs.
5 x 5 x 9/16	16½	“	1¾ x 1¾ x 3/16	2¾	“
4 x 4 x ½	12½	“	1½ x 1½ x 3/16	2	“
3½ x 3½ x 7/16	9	“	1¼ x 1¼ x 3/16	1½	“
3 x 3 x ⅜	7	“	1 x 1 x ⅛	1	“
2½ x 2½ x 5/16	5	“	¾ x ¾ x ⅛	⅝	“
2¼ x 2¼ x ¼	4¼	“			

TEE IRON.

Weight Per Linear Foot.

5 x 8 x ⅝	30	Lbs.	2¼ x 2¼ x ¼	4	Lbs
7 x 6 x ⅝	30	“	2 x 2 x ¼	3¼	“
6 x 3 x ½	16½	“	1¾ x 1¾ x ¼	3	“
4 x 4 x ½	14	“	1½ x 1½ x ¼	2¾	“
3½ x 3½ x ½	12½	“	1¼ x 1¼ x ¼	2¼	“
3 x 3 x ⅜	7¾	“	1 x 1 x ⅛	1	“
2½ x 2½ x ½	8	“	¾ x ¾ x ⅛	⅝	“
2½ x 2½ x 5/16	5	“			

PLATE I


PATTERN FOR CYLINDER
O
P
R
1 2 3 4 5 4 3 2 1
ELEVATION
PLAN
PATTERN FOR OPENING IN CONE
A
B
C
E
F
G
H
I
J
K
L
M
N
T
A¹
a b c d e
a' b' c' d' e'
a'' b'' c'' d'' e''
a''' b''' c''' d''' e'''
1' 2' 3' 4' 5'
1'' 2'' 3'' 4'' 5''
f

EXAMINATION PLATES.

PLATE I.

The plates of this Instruction Paper should be laid out the same size as explained in the course on Tinsmith's Work. Before starting these plates the student should first practice on other paper and make models of stiff cardboard to prove the accuracy of the patterns. When the problem is thoroughly mastered and understood, copy and send in your best drawing for examination and correction.

The first problem given is the intersection and development of a cylinder and a right cone, whose lines of axis run parallel to each other. First draw the base of the cone B C 4¼ inches long, placing B 1½ inches from the border line, and the line C B 5¼ inches above the bottom line. Make the vertical height of the cone 3½ inches, and draw the lines A B and A C. Through A draw the center vertical line J G, on which 2½ inches below the base line C B establish the point I. Now with I as center and ½ of C B as radius, describe the circle E F G H, which represents the plan of the cone. From A on the line A C measure down one inch as shown at e', from which erect a vertical line e' K ¾-inch high. From K draw the horizontal line K L equal to 1⅜ inches, and from L drop a perpendicular intersecting the side of the cone at M. Directly above L K in its proper relative position ¼-inch above L K, with N as center draw the circle shown, which represents a section through L K. Through the center N draw the horizontal line a e. Now divide the half upper section N into an equal number of spaces as shown by a b c d e, from which points drop vertical lines intersecting the side of the cone A C at a' b' c' d' and e', and from these points, draw horizontal lines, intersecting the opposite side A B from a'' to e''.

The next step is to construct planes in plan as follows: From the various intersections a'' to e'' in elevation, drop vertical lines intersecting the horizontal line H F in plan drawn through the center I, at a''' b''' c''' d''' and e'''. Then using I as center and distances to points a''' to e''' as radii, strike the various circles shown. From the center of the section N in elevation extend the line intersecting H F in plan at f; then using f as center and N a

or N *e* in elevation as radius, describe the circle 1–3–5–3 in plan, cutting the various planes at 1, 2, 3, 4, and 5 on both sides. Now, from the various points of intersection on the various planes in plan, erect lines intersecting similarly lettered planes in elevation as shown at 1′, 2′, 3′, 4′, and 5′, through which trace a line as shown, which represents the line of intersection between the cylinder and right cone.

For the pattern for the cylinder proceed as follows: Extend the line K L of the cylinder in elevation as shown by O P, placing the distance 1 from the margin line 2½ inches. Now starting from 1, lay off on O P the stretchout of the section *f* in plan, the spaces being designated by similar figures on O P. From these small figures and at right angles to O P, draw lines which intersect with lines drawn from similarly numbered intersections on the line of intersection in elevation parallel to O P. Trace a line through points thus obtained. Then will O P R be the full pattern for the cylinder.

The pattern for the right cone is developed as has already been described in the Tinsmith's Course, and for that reason will be shown only the method how to obtain the pattern for the opening in the cone to miter with the cylinder. For this proceed as follows: Draw radial lines from I in plan through the intersections 1, 2, 3, 4, and 5, cutting the outer curve E F G H at 1″, 2″, 3″, 4″, and 5″, respectively. Now with A B in elevation as radius and A^1 as center, describe a short arc as S T. Place the arc as far above the margin line as the plan G, and have S T central between the plan and margin line. From A^1 drop a vertical line intersecting the arc S T at 1″. Now starting from 1″, set off on either side of the center line A^1 1″ the distances shown in plan from 1″ 5″ to 4″ to 2″ to 3″, as shown by similar numbers on S T. From these points draw radial lines to A^1. Now using A^1 as center and with radii equal to A *e*′, A *d*′, A *c*′, A *b*′, and A *a*′ in elevation, describe arcs intersecting respectively the radial lines A′ 1″ at *e*″, 2″ 2″ at *d*″ *d*″, 3″ 3″ at *c*″ *c*″, 4″ 4″ at *b*″ *b*″, and A′ 5″ at *a*″. Through these intersections trace a line as shown, which will be the desired opening.

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ASTOR, LENOX AND
TILDEN FOUNDATION

PLATE II

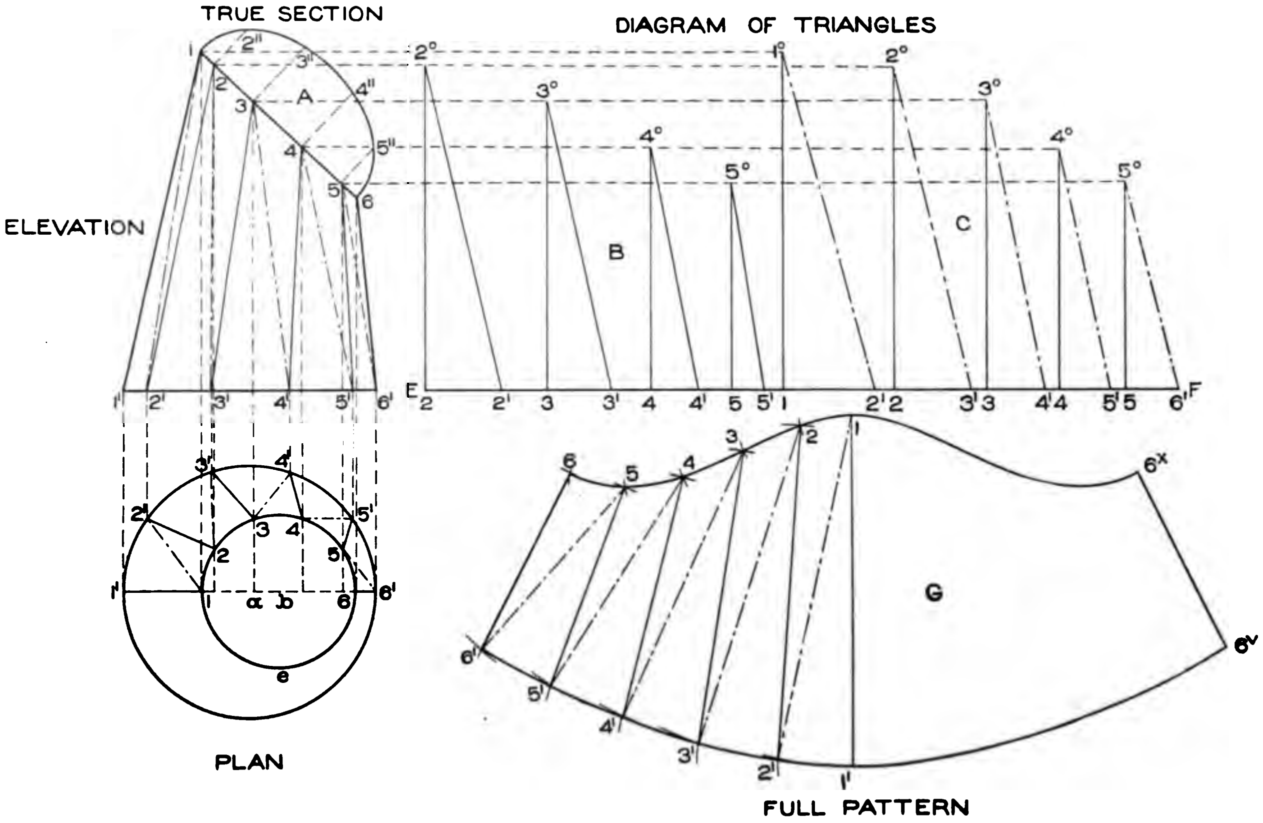

TRUE SECTION
DIAGRAM OF TRIANGLES
ELEVATION
PLAN
FULL PATTERN
A
B
C
G
E
F
1
2
3
4
5
6
2''
3''
4''
5''
1°
2°
3°
4°
5°
1'
2'
3'
4'
5'
6'
a
b
e
6x
6v

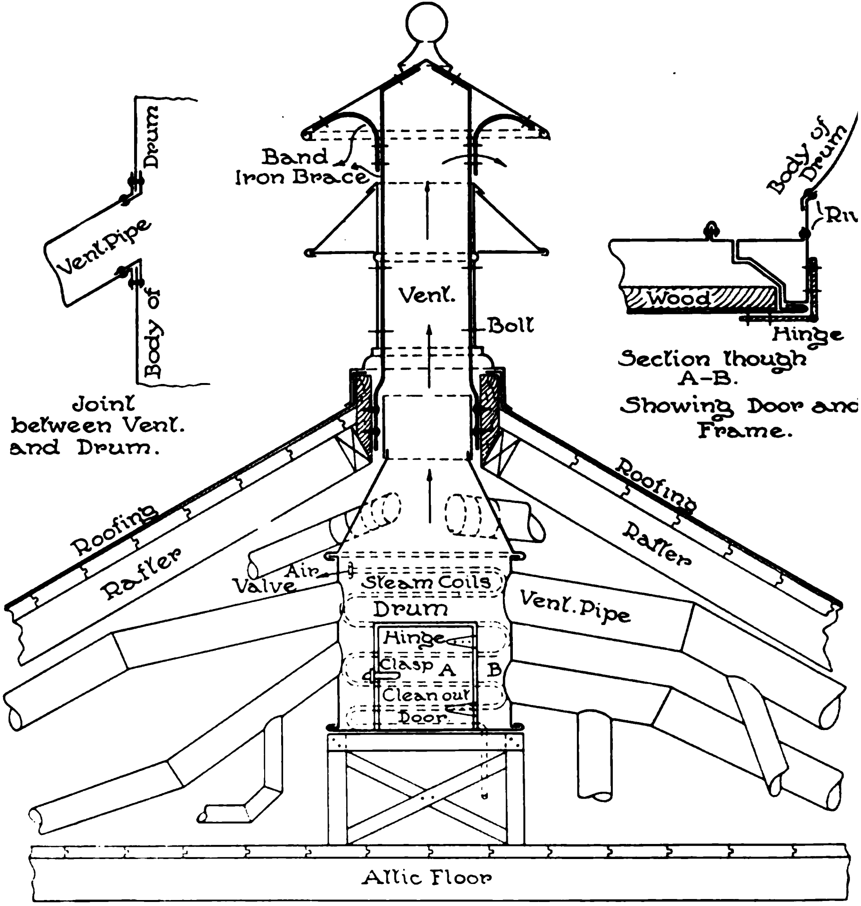
PLATE II.

This problem will give an examination on triangulation, being the development of an irregular solid whose bottom and top are round when viewed on horizontal planes, the top plane being cut off at an angle of 45° to the base line. First draw the base line 1′-6′, $2\frac{3}{4}$ inches long, placing the point 1′ 2 inches from the margin line, and the line 1′-6′ in the center of the sheet. Three inches above the bottom margin line draw the horizontal line 1′-6′ in plan; then with *a* as center and radius equal to one-half of 1′-6′ in elevation, draw the circle shown in its proper position below the line 1′-6′ in elevation. Now $\frac{1}{4}$ inch to the right of *a* on the line 1′-6′ in plan, establish *b*, which use as a center, and with $\frac{13}{16}$-inch radius describe the inner circle 1-3-6-*e*, which represents the upper horizontal plane of the irregular article. From the points 1 and 6 in plan, erect the vertical lines 1-1 and 6-6, making the height of the line 1-1 above the base line 1′-6′ in elevation $3\frac{3}{4}$ inches, and from the point 1 in elevation draw the line 1-6 at an angle of 45° intersecting the vertical line 6-6 at 6. Now draw lines from 1 to 1′ and from 6 to 6′, which completes the elevation.

Now divide the half plan into an equal number of parts (in this case 5) as shown by the small figures 1′ to 6′. In the same manner divide the inner circle into the same number of parts as shown from 1 to 6. Now draw solid lines from 1′ to 1, 2′ to 2, 3′ to 3, 4′ to 4, 5′ to 5, and 6′ to 6; and dotted lines from 1 to 2′, 2 to 3′, 3 to 4′, 4 to 5′, and 5 to 6′. From the intersections 1′ to 6′ on the outer plan, erect lines intersecting the base line in elevation from 1′ to 6′. In a similar manner, from the intersections on the inner curve in plan erect lines intersecting the top plane of the article from 1 to 6. Now connect lines in elevation from 2 to 2′, 3 to 3′, etc., although these lines are not necessary in the development of the pattern, but are given only to show their relationship to similar lines in plan. The solid and dotted lines in plan represent the bases of triangles, which will be constructed, whose altitudes are equal to similarly numbered vertical heights in elevation. The construction of these triangles is shown at B and C, B representing the triangles on solid lines in plan, and C the triangles on dotted lines in plan. Construct these triangles as follows: Extend the line 1′-6′ in elevation as E F, the point 6′ on E F to be placed 1 inch from the margin line. Now take the various distances of the dotted lines in plan as 6′ to 5, 5′ to 4, 4′ to 3, 3′ to 2, and 2′ to 1, and place them on the line E F as shown by similar numbers. Now from the small figures 1, 2, 3, 4, and 5 on the line E F, erect lines, which intersect by lines drawn from similarly numbered intersections on 1-6 in elevation, parallel to E F, thus obtaining the points 1°, 2°, 3°, 4°, and 5°. Then draw lines from 1° to 2′, 2° to 3′, 3° to 4′, 4° to 5′, and 5° to 6′, which will represent the diagram of triangles on dotted lines in plan, the slant lines representing the true lengths on the finished article. In precisely the same manner obtain the diagram of triangles B on solid lines in plan. For example, take the distance of 2-2′ in plan, and place it as shown by 2-2′ on the line E F; from 2 at right angles to E F draw the line 2-2° equal to the vertical height to 2 in elevation, and draw a line from 2° to 2′, which is the true length on 2-2′ in plan. It now becomes necessary to obtain a true section on the line 1-6 in elevation. Therefore at right angles to 1-6 and from the various intersections 1 to 6, draw lines as shown. Now measuring in each instance from the line 1′-6′ in plan, take the various distances to points 2, 3, 4, and 5, and place them in A on similarly numbered lines, measuring in each instance from the line 1-6 in elevation, thus obtaining the points 2″ to 5″. A line traced as shown will be the half section on 1-6 in elevation.

For the pattern proceed as follows: Draw any line as 1-1′ in G equal to 1-1′ in elevation. Now with radius equal to 1′-2′ in plan, and 1′ in G as center, describe the arc 2′. Then using 1 in G as center, and 1°-2′ in C as radius, intersect the arc 2′ in G. Now with radius equal to 1-2″ in the true section, and 1 in G as center, describe the arc 2, which intersect by an arc struck from 2′ as center and with 2°-2′ in B as radius. Proceed in this manner, using alternately as radii, first the divisions in the outer curve in plan, then the hypothenuses or slant lines in C; the divisions in the true section A, then the length of the slant lines in B, following the numbers in regular order until the last line 6-6′ in G is obtained, this line being obtained from 6-6′ in elevation. Trace lines as shown from 1 to 6 and from 1′ to 6′, which give the half pattern. Trace the other half opposite the line 1–1′ as shown by $6^x 6^v$. Then will $6\text{–}1\text{–}6^x\text{–}6^v\text{–}1'\text{–}6'$ be the full pattern with joint at 6–6′ in elevation

CONSTRUCTION DRAWING
SHOWING
SHEET METAL DRUM AND VENTILATOR IN VENTILATION WORK



Sectional view showing ventilation pipes connected to drum in attic also steam coils in drum to create suction.

SHEET METAL WORK.

PART II.

PROBLEMS FOR LIGHT GAUGE METAL.

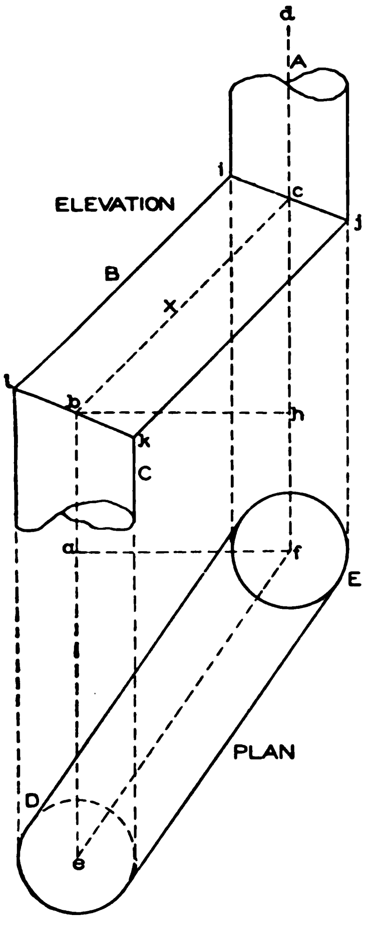


Fig. 65.

It is often the case that the sheet metal worker receives plans for vent, heat, or blower pipes to be constructed, in which the true lengths and angles are not shown but must be obtained from the plans or measurements at the building.

Figs. 65 and 66 show the principles employed for obtaining the true angles and lengths in oblique piping, it being immaterial whether the piping is round, square, or oval in section. The only safe way in obtaining these angles is to use the center line as a basis and after this line has been obtained, build the pipe around it, so to speak. In Fig. 65 let A B C represent the elevation of the elbow shown in plan by D E. Through the center of the pipes draw the center line *a b c d* which intersect the center lines of the pipe in plan at *e* and *f*. In elevation the rise of the middle piece B on the center line is equal to *h c* and projects to the right a distance equal to *b h*, shown in plan by *e f*; this same pipe projects forward in plan a distance equal to *e a*. While the miter lines in elevation *i j* and *k l* have been drawn straight, they would in reality show curved lines; those lines have not been projected as there is no necessity for doing so.

With the various heights and projections in plan and elevation the true length and true angles are obtained as shown in Fig. 66, in which draw the horizontal line *e f* equal to *e f* in plan in Fig. 65. Take the height from *h* to *c* and place it from *f* to *c* in Fig. 66 on a vertical line erected from *f*. Draw a line from *e* to *c* which is the true length on the center line of the pipe shown by B in elevation in Fig. 65. From the points *e* and *c* in Fig. 66 draw perpendicular lines, making Y *e* X and X *c* Z = the true angles shown by *a b* X and X *c d* respectively in Fig. 65. On either side of the center line in Fig. 66 lay off the half diameter of the pipe as shown, and in its proper position draw the profile W.

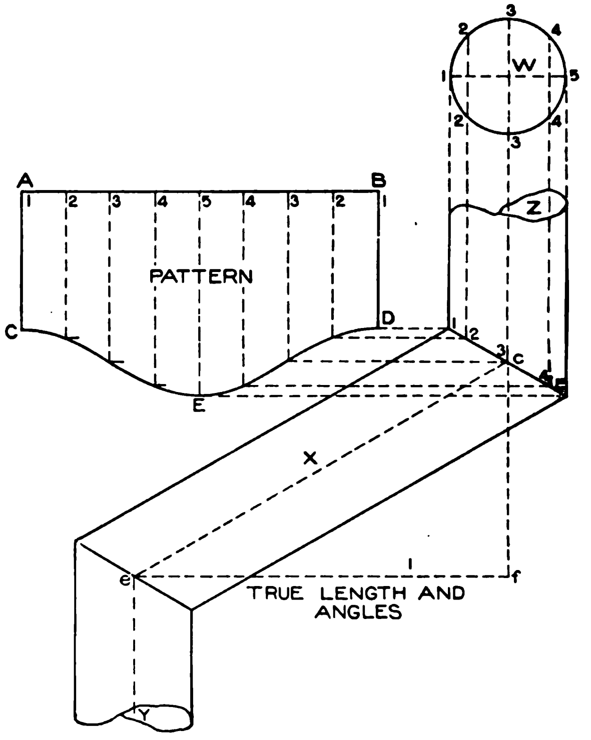


Fig. 66.

Divide this into equal spaces and obtain the pattern A B D E C in the usual manner. As both angles are similar the miter cut C E D can be used for all of the patterns. In drawing this problem for practice make the diameter of the pipe 2 inches, the height from *h* to *c* 3¾ inches in Fig. 65, the projection *b* to *h* 3¾ inches, and the projection in plan *e* to *a* 5¼ inches.

Our next problem is that of a rain-water cut-off, a perspective view of which is shown in Fig. 67. While the miter cuts in this problem are similar to elbow work the intersection between the two beveled arms, and the cut-off or slide on the inside require attention. Make the diameter of the three openings each 2 inches; A to B (Fig. 68) 1½ inches. From B at an angle of 45° draw B C 3¼ inches and C D 2 inches. From G draw the vertical miter line G *h*. Make the distance from B to T ½ inch. Place the line *d e* of the cut-off ⅛ inch above the line T U as indicated at *a* and the line *e c* to the right of *h* G, as indicated by *b*, a distance of $\frac{3}{16}$ inch. Parallel to G H draw *c d* giving slight play room between G H, intersecting *e d* and *e c* at *d* and *c* respectively. From *e* at right angles to *d c*, draw a line as shown, intersecting *h* G at *f*, which is the pivot on which the cut-off *c d e* will turn either right or left. The angles of the pipes on opposite sides are constructed in similar manner; A B C D E F G H I J K L M will be the elevation, N, the section on A M and O P R S the section on I J. B T U L shows how far the upper tube projects into the body under which the scoop *e d e* turns right and left to throw the rain water into either elbow as desired. The pattern for the upper piece A T U M is a straight piece of metal whose circumference is equal to N.

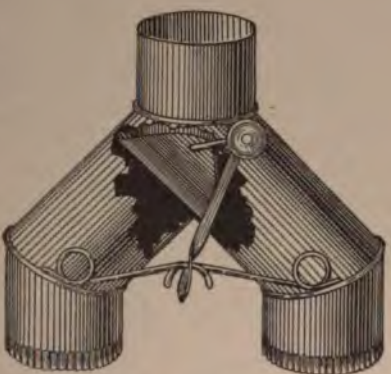


Fig. 67.

For the pattern for (A), divide the half section O P R into equal spaces as shown, from which erect lines intersecting the miter line H K as shown, and from which, parallel to K L and H G, draw lines intersecting the joint lines G *h* L as shown. As none of the lines just drawn intersect the corner h, it will be necessary to obtain this point on the half section O P R from which the stretchout of the pattern is taken. Therefore from h, parallel to L K draw h h' intersecting H K at h', from which, parallel to K J, drop a line intersecting the profile O P R S at h''. At right angles to L K draw stretchout of O P R S as shown by similar numbers on T^1 U^1, through which at right angles to T^1 U^1 draw lines which are intersected by lines drawn at right angles to L K from similar intersections on G h L and H K. A line traced through points thus obtained as shown by X Y Z V W will be the pattern for (A). From f' in the elevation at right angles to L K project a line intersecting the miter cut X Y Z at f'' and f'''. At f'' and f''' holes are to be punched in which the pivot f' of the scoop e' d e in elevation will turn.

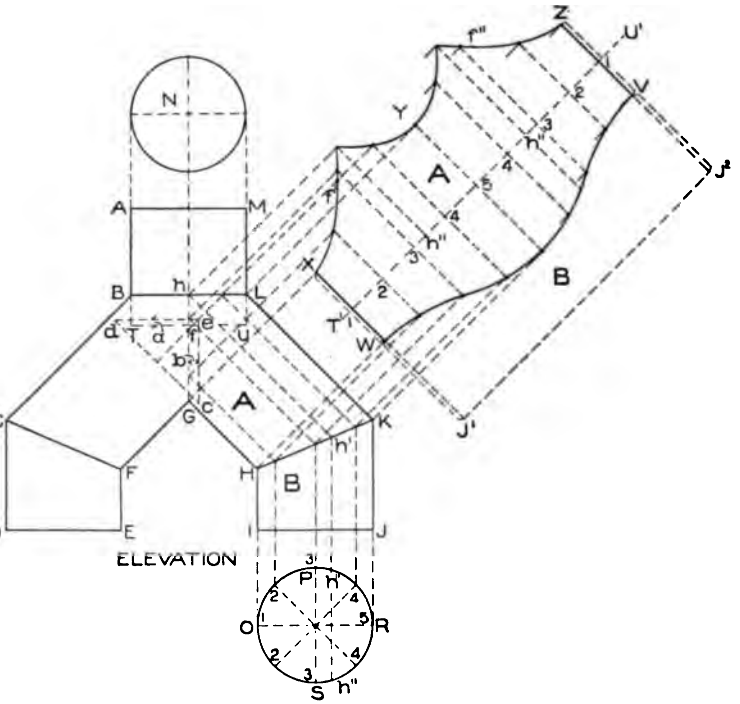


Fig. 68.

While the pattern for (B) can be obtained as that for (A) was obtained, a short method is to take the distance K to J and place it as shown from W to J^1 and V to J^2 on the lines of the pattern X W and Z V respectively extended. W V J^2 J^1 will be the pattern for B.

To avoid a confusion of lines in the development of the scoop or cut-off *c d e*, this has been shown in Fig. 69 in which *d e c* is a reproduction of *d e c* in Fig. 68. A true section of the scoop must now be drawn on *x e* in Fig. 69 so that its dimensions will allow it to turn easily inside of the joint line G *h* in elevation in Fig. 68. Therefore draw any horizontal line as 4 5 in Fig. 69, at right angles to which from *f* draw a vertical line intersecting 4 5 at *f*. Now take a distance $\frac{1}{16}$ inch less than one-half the diameter of O R in Fig. 68, and place it in Fig. 69 on either side of the line 4 5 on the vertical line just drawn as shown from *f* to 2 and *f* to 2′. Extend *d c* till it intersects 4 5 at 4. Draw a line from 4 to 2′; by bisecting this line we obtain the line *a b* intersecting 4 5 at *i*. Then with *i* as center and *i* 2′ as radius, describe the arc 2′ 2. From 2 and 2′ draw horizontal lines equal to *f e* as shown by 2 1 and 2′ 1′. Then will 1 4 1′ be the true section on *x e*. Divide the half section into equal spaces as shown from 1 to 4, from which erect lines intersecting *c e* and *e d*. Extend *x e* as *x j*, upon which place the stretchout of 1 4 1′ as shown by similar numbers on *x j*, through which draw vertical lines. These lines intersect with horizontal lines drawn from similar intersections on *d e c*. Through points thus obtained draw the line 1 *n* 1′ *m* which is the desired pattern. As the pivot hole *f* falls directly on line 2, then *f‴ f″* will be the position of the holes in the pattern. Laps must be allowed to all patterns.

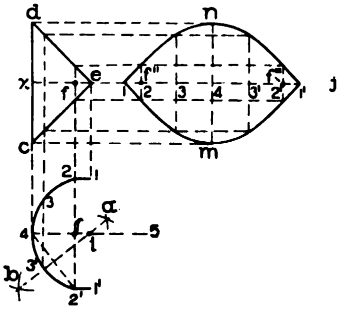


Fig. 69.

In putting up rectangular hot air pipe it is often the case that the pipe will be placed in the partition of one story, then has to fall forward and twist one quarter way around to enter the partition of the upper story which runs at right angles to the lower one. A perspective view showing this condition is shown in Fig. 70, where the upper opening turns one quarter on the lower one and leaning to the right as much as is shown in Fig. 71 in plan. This problem is known as a transition piece in a rectangular pipe.

Full size measurements are given in Fig. 71 which should be drawn one-half size. The height of the transition piece is 1 foot 8 inches, the size of the openings, each 4×10 inches turned as shown, two inches to the left and two inches above the lower section as shown. From the plan construct the front and side elevations as shown by the dotted lines. A B C D and E F G H will then be the front and side elevations of the transition piece respectively

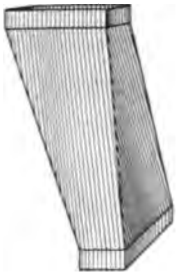


Fig. 70.

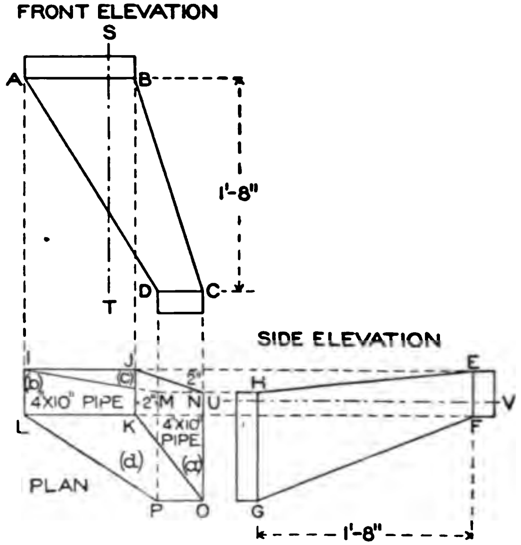


Fig. 71.

equal to 20 inches or 10 inches for practice. Number each side of the plan (*a*), (*b*), (*c*), and (*d*). Through the front and side elevations draw the vertical and horizontal lines S T and U V respectively at pleasure. These lines are only used as bases for measurements in determining the patterns. For the pattern for the side marked (a) in plan take the length of B C and place it on the vertical line B C in Fig. 72. Through the points B and C draw the horizontal lines E F and H G, making B F and B E, and C G and C H equal respectively to the distances measured from the line U V in Fig. 71 to points F, E, G, H. Draw lines from E to H and F to G in Fig. 72, which is the pattern for (a).

For the pattern for (b) in Fig. 71 take the distance of A D, and place it as shown by A D in Fig. 72; through A and D draw E F and H G, making A F and A E, and D G and D H equal respectively to the distances measured from the line U V in side elevation in Fig. 71 to points F, E, G, H. Draw lines from E to H and F to G in Fig. 72, which will be the pattern for (b). In similar manner obtain the patterns for (c) and (d) in plan in Fig. 71. The lengths of E H and F G are placed as shown by similar letters in Fig. 72, while the projections to A, B, C, D are obtained from A, B, C, D in front elevation in Fig. 71, measuring in each instance from S T.

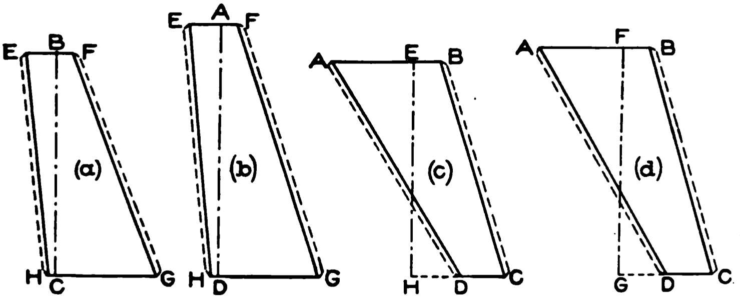


Fig. 72.

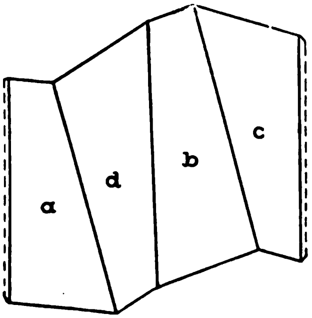


Fig. 73.

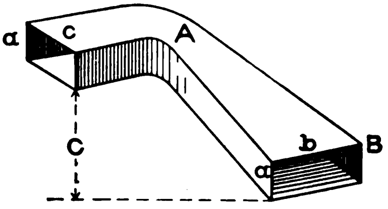


Fig. 74.

If desired the top and lower flange shown in the perspective in Fig. 70 can be added to the patterns in Fig. 72. Laps are allowed to the patterns to allow for double seaming at corners, if, however, the pattern should be required in one piece, it would only be necessary to join the various pieces in their proper positions as shown by *a d b c* in Fig. 73, which would bring the seam on the line J N in plan in Fig. 71.

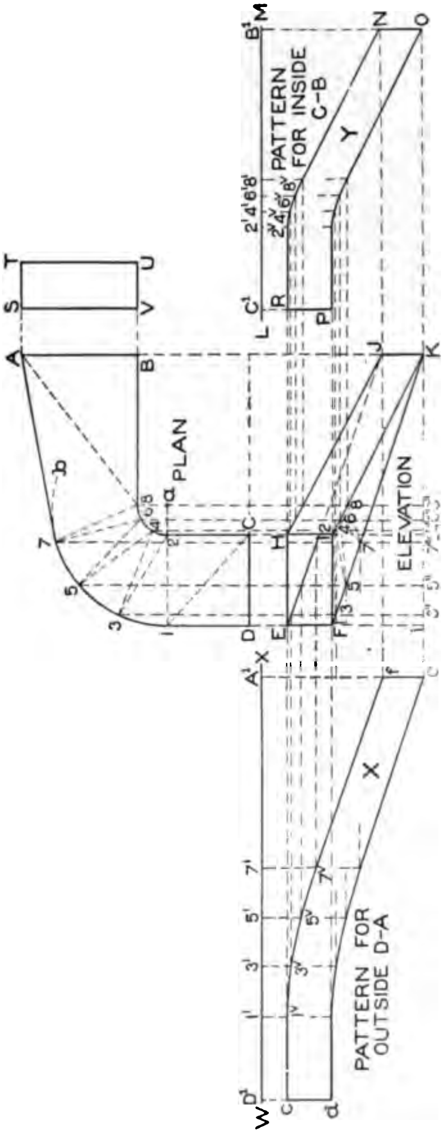


Fig. 75.

In Fig. 74 is shown a perspective view of a curved rectangular chute the construction of which arises in piping and blower work. The problem as here presented shows the sides *a* and *a* in vertical planes having the same height, while the bottom *b* has more width than the top *c*. The top opening is to rise above the bottom opening a given distance equal to C. First draw the plan and elevation as shown in Fig. 75, make A B equal to 2 inches, B 8 2½ inches; with a radius equal to ½ inch, with *a* as center draw the quarter circle 8 2. From 2 draw the vertical line 2 C equal to 1⅜ inches and draw C D equal to 1½ inches. Make D 1 equal to C 2 and using *a* as center and *a* 1 as radius draw the arc 1 *b*. From A draw a line tangent to 1 *b* as A 7. A B C D will be the plan of the chute. In line with A B draw the section S T U V. In line with D C draw the section E F I H as shown. Place the desired rise of the chute as shown by F *i* in elevation and from *i* draw a horizontal line as *i* K, which intersect by a line drawn from A B in plan as shown. Make K J equal to F E and draw the lines F K, K I, and E J, J H. F E J K is the elevation of the outside curve, H I K J the inside curve, F I K the bottom, and E H J the top.

Having the plan and elevation in position we will first draw the pattern for the two vertical sides. For the pattern for the side of the chute shown by B C in plan proceed as follows: Divide the inner curve 2 to 8 into equal parts as shown by 2-4-6 and 8, from which points drop lines intersecting the inside of the chute in plan H J K I as shown. At right angles to J K draw L M, upon which place the stretchout of B C in plan as shown by similar letters and numbers on L M, through which draw vertical lines which intersect lines drawn parallel to L M from H J. Through points thus obtained draw the line R 2^V 4^V 6^V 8^VN. The same method can be employed for the curve P O, but as the height H I and J K are equal, having a common profile B C, take the height of H I or J K and place it on vertical lines as R P and N O and trace the curve R N as shown by P O. N O P R is the pattern for C B in plan; To obtain the pattern for the outside curve divide the curve 1-7 into equal parts as shown, from which drop vertical lines intersecting similar points in E J K F, in elevation at right angles to E F draw W X, upon which place the stretchout of D A in plan as shown. From the divisions on W X drop vertical lines, which intersect by lines drawn from similar numbered intersections on E J. Trace a line through these points as shown by *e f* and draw *d e* as explained in connection with the inside pattern. *c d e f* is the pattern for the outside of the chute shown in plan by D A.

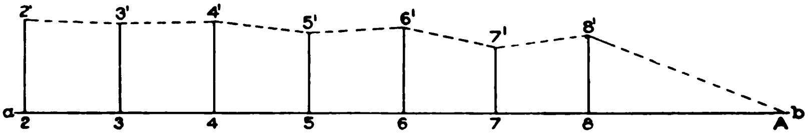


Fig. 76.

As both the top and bottom of the chute have the same bevel, the pattern for one will answer for the other. Connect opposite points in plan as shown from C to 1 to 2 to 3 up to 8, then to A. In similar manner connect similar points on the bottom in elevation as shown from 1 to 2 up to K. The lines in plan represent the bases of the sections whose altitudes are equal to the various heights in elevation, measured from *i* K. Take the various lengths from 2 to 3 to 4 to 5 to 6 to 7 to 8 to A in plan and place them as shown by similar numbers on the horizontal line *a b* (Fig. 76); through *a b* draw vertical lines, equal in height to similar numbers in elevation, in Fig. 75, measured from the line *i* K. For example take the distance 4 5 in plan and place it as shown by 4 5 in Fig. 76. Erect perpendiculars 4 4′ and 5 5′ equal to 4″ 4 and 5″ 5 in elevation in Fig. 75. Draw a line from 4′ to 5′ in Fig. 76, which is the true length of 4 5 in plan in Fig. 75. Proceed in similar manner for the balance of the sections. Take a tracing of 1 2 C D in plan and place it as shown by 1, 2, C, D in Fig. 77. Now using 1 as center and 1^V 3^V in (*x*), in Fig. 75, as radius, describe the arc at 3, in Fig. 77, which is intersected by an arc, struck from 2 as center, and 2′ 3′, in Fig. 76, as radius. Now with radius equal to 2^V 4^V in (Y) in Fig. 75 and 2 in Fig. 77 as center, describe the arc at 4 which is intersected by an arc, struck from 3 as center and 3′ 4′, Fig. 76, as radius. Proceed in this manner, using alternately as radius, first the divisions in the pattern (X), Fig. 75, then the slant lines in Fig. 76, the divisions in the pattern (Y), Fig. 75, then again the lines in Fig. 76 until the line 7 8, Fig. 77, has been obtained. Then using 7 as center, with a line equal to $7^V f$ in (X), Fig. 75, as radius, describe the arc A, Fig. 77, which is intersected by an arc struck from 8 as center and 8′ A, Fig. 76, as radius. Then with radius, equal to 8^V X in (Y), Fig. 75, and 8, Fig. 77, as center, describe the arc B, which is intersected by an arc, struck from A as center and A B in plan in Fig. 75 as radius. Trace lines through points thus obtained in Fig. 77,

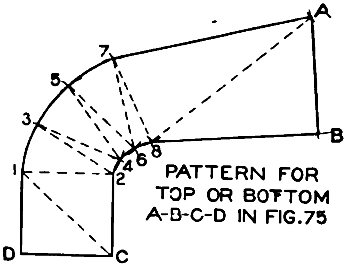


Fig. 77.

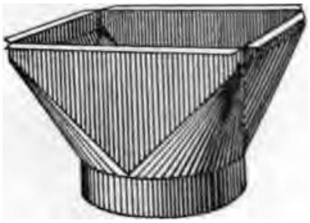


Fig. 78.

and A B C D will be the desired pattern. Laps must be allowed on all patterns for double seaming the corners.

In Fig. 78 is shown a perspective view of a hopper register box usually made from bright tin or galvanized iron in hot air piping. In drawing this problem, the student should first draw the half plan, making the semicircle $3\frac{3}{4}$ inches diameter, and placing it directly in the center of the rectangular top, which is $3\frac{3}{4}$ inches wide and $5\frac{3}{4}$ inches long. Draw the elevation from the plan as shown by A B C D E F G H, making the vertical height V W, $2\frac{1}{4}$ inches, and the flanges at the top and bottom each $\frac{1}{2}$ inch. I K L M in plan is the horizontal section on A B in elevation and O P R the section on E F.

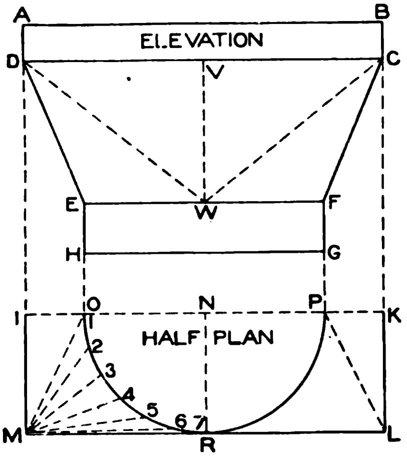


Fig. 79.

The pattern will be developed by triangulation, and the first step is to develop a set of triangles. Divide the quarter circle O R into equal spaces, as shown by the numbers 1 to 7 in plan, from which draw lines to the apex M. These lines represent the bases of triangles whose vertical height is equal to V W in elevation. Therefore, in Fig. 80, draw any horizontal line as T U, upon which place the various lengths M 1, M 2, M 3, etc.) Fig. 79) as shown by similar numbers on T U. From T U erect the line T S equal to the vertical height V W (Fig. 79). Then draw the hypotenuses S 1, S 2, S 3, etc., in Fig. 80, which represent the true lengths of similar numbered lines in plan in Fig. 79.

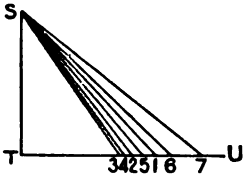


Fig. 80.

For the half pattern with seams on I O and P K in plan, take a tracing of D V W in elevation and place it as shown by D V 7 in Fig. 81. Now using D as center, and with radii equal to the various slant lines in Fig. 80 from S 1 to S 7 strike small arcs as shown from 1 to 7 in Fig. 81. Set the dividers equal to the spaces contained in O R, in Fig. 79, and starting from point 7, in Fig. 81, step from one arc to another until 1 is obtained. Then using 1 as center and E D (Fig. 79) as radius describe the arc D′ in Fig. 81. With D as center and M I in plan in Fig. 79 as radius, draw another arc intersecting the one previously drawn at D′. Draw a line from 1 to D′ to D in Fig. 81, 7 1 D′ D V is the quarter pattern, and the left-hand side of the figure may be made by tracing the quarter pattern reversed as shown by V C D″ 1′ 7. Take the distance of the flange D A in elevation in Fig. 79 and place it at right angles to the line D′ D, D C, C D″ as shown respectively by A″ A′, A A^O and A^V A^X, which completes the half pattern with laps allowed as shown

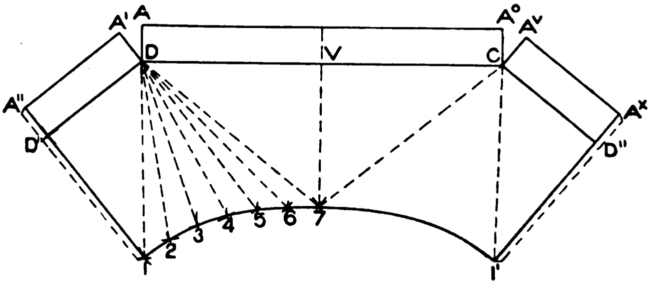


Fig. 81.

The pattern for the collar E F G H in elevation in Fig. 79 is simply a straight strip of metal, equal to the circumference of O P R in plan.

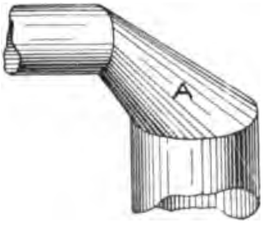


Fig. 82.

It is often the case that two unequal pipes are to be connected by means of a transition piece as shown by A in Fig. 82, the ends of the pipes being cut at right angles to each other. As the centers of both pipes are in one line when viewed in plan, making both halves of the transition piece equal, the problem then consists of developing a transition piece, from a round base to a round top placed vertically. Therefore in Fig. 83 draw 1 5 equal to $2\frac{1}{4}$ inches, and at an angle of 45 draw 5 6 $1\frac{3}{4}$ inches. At right angles to 1 5 draw 6 10 4 inches long and draw a line from 10 to 1. On 1 5 draw the semicircle 1 3′ 5, and on 6 10 draw the semicircle 6 8′ 10.

Divide both of these into equal spaces as shown, from which draw lines perpendicular to their respective base lines. Connect opposite points as shown by the dotted lines, and construct a diagram of sections as shown in Fig. 84 whose bases and heights are equal to similar numbered bases and heights in Fig. 83. For example, take the distance 4 8 and place it as shown by 4 8 in Fig. 84, from which points erect the vertical lines 4 4′ and 8.8′ equal to 4 4′ and 8 8′ in Fig. 83. Draw a line from 4′ to 8′, Fig. 84, which is the true length on similar line in Fig. 83. For the pattern take the distance of 1 10 and place it as shown by 1 10 in Fig. 85. Using 1 as center, and 1 2′, Fig. 83, as radius, describe the arc 2 in Fig. 85; intersect it by an arc struck from 10 as center and 10 2′, Fig. 84, as radius. Then using 10 9′ in Fig. 83 as radius, and 10, Fig. 85, as

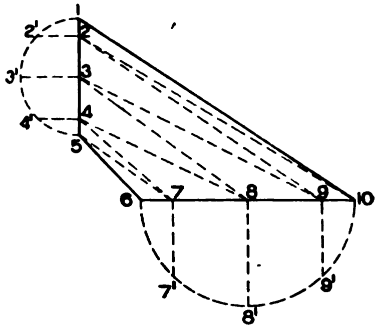


Fig. 83.

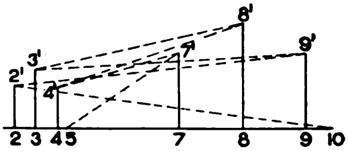


Fig. 84.

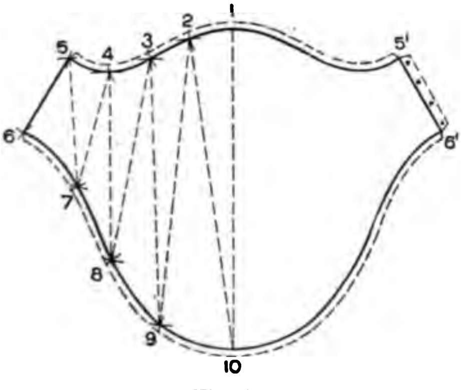


Fig. 85.

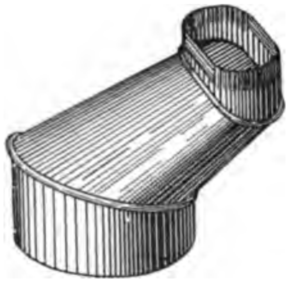


Fig. 86.

center, describe the arc 9, and intersect it by an arc struck from 2 as center, and 2′ 9′, Fig. 84, as radius. Proceed in this manner using alternately as radii, first the divisions in the half profile 1 3′ 5, Fig. 83, then the length of the proper hypotenuse in Fig. 84, then the divisions in 6 8′ 10 in Fig. 83; then again the hypotenuse in Fig. 84 until the line 5 6 in Fig. 85 has been obtained, which is equal to 5 6 in Fig. 83. Laps should be allowed for riveting and seaming as shown.

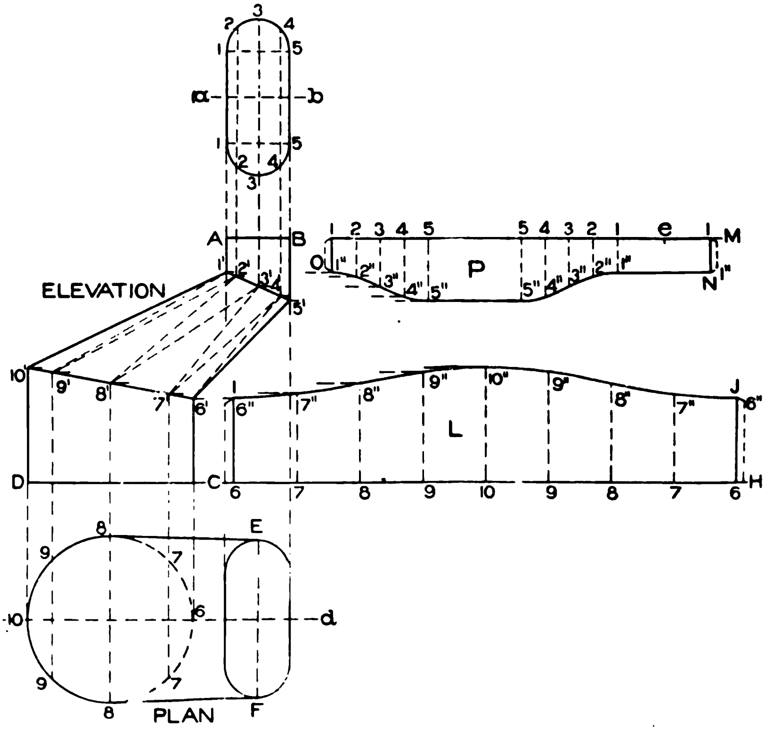


Fig. 87.

In Fig. 86 is shown a perspective of an offset connecting a round pipe with an oblong pipe, having rounded corners.

The first step is to properly draw the elevation and plan as shown in Fig. 87. Draw the horizontal line A B equal to one inch, B 5′ one inch, and from 5′ at an angle of 45° draw 5′ 6′ equal to 2¼ inches and 6′ C 1¼ inches. Make the diameter C D 2¾ inches and D/0′ 1¾ inches. Make A 1′ ½ inch and draw a line from 1′ to

10′ which completes the elevation. Directly above the line A B draw the section of the oblong pipe, making the sides 1 1 and 5 5 equal to 1½ inches, to which describe the semicircles on each end as shown. In similar manner draw the section on D C, which is shown by 6 8 10 8. A duplicate of the oblong pipe is also shown in plan by E F, showing that the centers of the pipe come in one line, making both halves symmetrical.

The patterns for the pipes will first be obtained. Divide the semicircular ends of the oblong section into equal parts, in this case four, also each of the semicircles of the round pipe in similar number of parts as shown respectively from 1 to 5 and 6 to 10. Draw vertical lines from these intersections cutting the miter line of the oblong pipe at 1′ 2′ 3′ 4′ 5′ and the miter line of the round pipe at 6′ 7′ 8′ 9′ and 10′. In line with A B draw B M, upon which place the stretchout of the oblong pipe as shown by similar numbers; from B M drop vertical lines intersecting the lines drawn parallel to B M from similarly numbered points on 1′ 5′. Trace a line through points thus obtained, and P N O will be the pattern for the oblong pipe. Now take the stretchout of the round pipe, and place it on C H; erect vertical lines as shown intersecting the lines drawn parallel to C H from similar intersections on 6′ 10′. I J H C is the pattern for the round pipe.

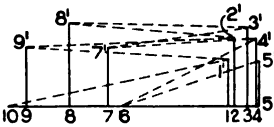


Fig. 88.

The transition piece 1′ 5′ 6′ 10′ will be developed by triangulation, and it is usual to obtain true sections on the lines 1′ 5′ and 6′ 10′; however, in this case it can be omitted because we have the true lengths of the various divisions on the lines 1′ 5′ and 6′ 10′ in the miter cuts in P and L respectively.

The next step is to obtain a diagram of sections giving the true lengths, for which proceed as follows: Connect opposite points in elevation as shown from 1′ to 9′ to 2′ to 8′ to 3′ etc., as shown. For example draw center lines through the oblong and round sections as shown by *a b* and *c d* respectively, and take the length of 1′ 10′ in elevation and place it as shown from 1 to 10 in Fig. 88. From 1 draw the vertical line 1 1′ equal to the height of 1 in the oblong section in Fig. 87 above the center line *a b*. As point 10 in plan has no height, it falls on the center line *c d* in plan, then draw a line from 1′ to 10 in Fig. 88. Now take the distance from 1′ to 9′ in elevation, Fig. 87, and place it as shown from 1 to 9 in Fig. 88. Erect the lines 1 1′ and 9 9′ equal to points 1 and 9 in the oblong and round sections in Fig. 87, measured respectively from the lines *a b* and *c d*. Draw a line from 1′ to 9′ in Fig. 87. Proceed in this manner until all of the sections are obtained. For the pattern proceed as shown in Fig. 89, in which draw any vertical line as *e* 10 equal to 1′ 10′ in elevation in Fig. 87. Now, with one-half of 1 1 in pattern P as *e* 1 as radius, and *e* in Fig. 89 as center, describe the arc 1 which is intersected by an arc struck from 10 as center and 10 1′, in Fig. 88 as radius. With radius equal to 10″ 9″ in pattern L in Fig. 87, and 10 in Fig. 89 as center describe the arc 9, which is intersected by an arc struck from 1 as center and 1′ 9′, in Fig. 88 as radius. Now, using as radius 1″ 2″ in pattern P in Fig. 87 and 1 in Fig. 89 as center, describe the arc 2 which is intersected by an arc struck from 9 as center and 9′ 2′ in Fig. 88 as radius.

Proceed in this manner, using alternately as radii, first the divisions in the pattern cut I J, Fig. 87, then the length of the slant lines in Fig. 88, the divisions in the cut O N in Fig. 87, then again the slant lines in Fig. 88 until the line 5 6 in pattern, Fig. 89, has been obtained. Then using 5 as center and 1 *e* in P, Fig. 87, as radius, describe the arc *e′* in Fig. 89, and intersect it by an arc struck from 6 as center and 6′ 5′ in elevation in Fig. 87 as radius. Draw lines through the various intersections in Fig. 89; 10 *e e′* 6 is the half pattern. By tracing it opposite the line *e* 10, as shown by *e* 1′ 5′ *e″* 6′ 10, the whole pattern, *e′ e e″* 6′ 10 6, is found. Laps should be allowed on all patterns for seaming or riveting both in Figs. 87 and 89.

In Fig. 90 is shown a perspective view of a three-way branch round to round, the inlet A being a true circle, and the outlets B, C, and D also being true circles, the centers of which are in the same vertical plane, thus making both sides of the branch symmetrical.

First draw the elevation and the various sections as shown in Fig. 91. Draw the center line *a b*. From *b* draw the center line of the branch C at an angle of 58° as shown by *b d*. Make the center lines *a b* and *b d* each $3\frac{1}{2}$ inches long. Make the half diameter of the branch B at the outlet $\frac{3}{4}$ inch, and the full diameter of the branch C at the outlet 1½ inches placed on either side of and at right angles to the center lines. Draw a line from *e* to *f*, and with *i* and *h* as centers and radii equal to ¾ inch draw arcs intersecting each other at *e*. Draw lines from *i* to *e* to *h*. In similar manner obtain A and the opposite half of B. A B C is the elevation of the three branches whose sections on outlet lines are shown respectively by G F and E and whose section on the inlet line is shown by D.

The next step is to obtain a true section on the miter line or line of joint *b c*. Knowing the height *b c* and the width at the bottom, which is equal to the diameter of D, the shape can be drawn at pleasure as shown in Fig. 92, *b c* is drawn equal to *b c*, Fig. 91, while *b d* and *b a* are equal to the half diameter D in Fig. 91. Now through *a c d* in Fig. 92 draw the profile at pleasure as shown, which represents the true section on *c b* in Fig. 91.

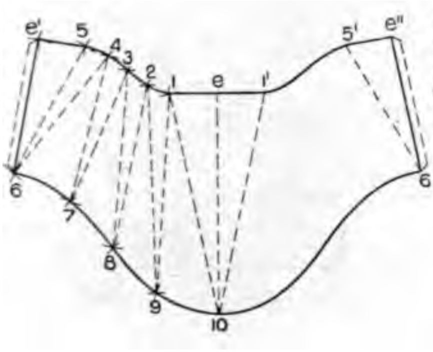


Fig. 89.

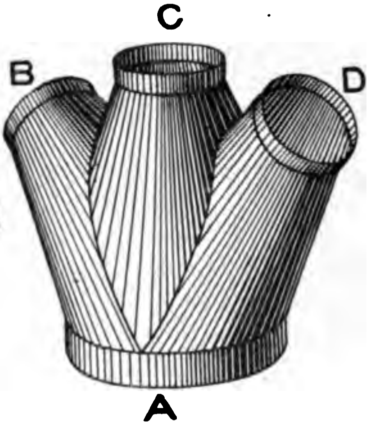


Fig. 90.

As the side branches A and C are alike, only one pattern will be required, also a separate pattern for the center branch both of which will be developed by triangulation. To obtain the measurements for the sections for the center branch B, proceed as shown in Fig. 93 where 1 4 5 8 is a reproduction of one-half the branch B in Fig. 91. As the four quarters of this center branch are alike only one quarter pattern will be developed; then, if desired, the quarter patterns can be joined together, forming one pattern. Now take a tracing of *c b a*, Fig. 92, and place it on the line 5 8 as shown in Fig. 93. Similarly take a tracing of the quarter profile F in Fig. 91 and place it on the line 4 1 in Fig. 93. Divide the two profiles 1′ 4 and 5 8′ each into the same number of spaces as shown respectively by points 1′ 2′ 3′ 4 and 5 6′ 7′ 8′, from which points at right angles to their respective base lines 1 4 and 5 8 draw lines intersecting the base lines at 1 2 3 4 and 5 6 7 8. Now draw solid lines from 3 to 6 and 2 to 7 and dotted lines from 3 to 5, 2 to 6, and 1 to 7. These solid and dotted lines represent the bases of the sections whose altitudes are equal to the various heights of the profiles in Fig. 93. The slant lines in Fig. 94 represent the true distances on similar lines in Fig. 93, as those in Fig. 95 represent the true distances on dotted lines in Fig. 93.

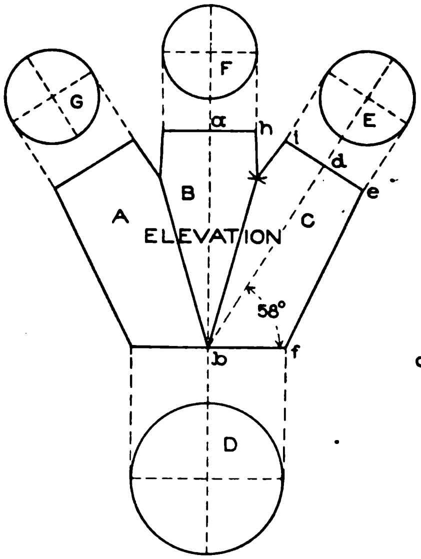


Fig. 91.

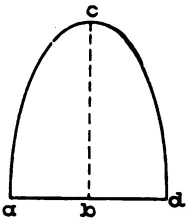


Fig. 92.

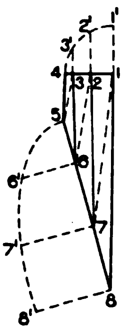


Fig. 93.

For the pattern take the length of 1′ 8′, Fig. 94, and place it as shown by 1 8 in Fig. 96, and using 8 as center and 8′ 7′ in Fig. 93 as radius draw the arc 7, which intersect by an arc struck from 1 as center and 1′ 7′ in Fig. 95 as radius. Then using 1′ 2′ in Fig. 93 as radius draw the arc 2, which intersect by an arc struck from 7 as center and 7′ 2′ in Fig. 94 as radius. Proceed in this manner until the line 4 5 in Fig. 96 has been obtained which equals 4 5 in Fig. 93. Trace a line through points thus obtained in Fig. 96, then will 1 4 5 8 1 give the quarter pattern.

If the pattern is desired in one piece trace as shown by similar figures, to which laps must be allowed for riveting.

As the two branches A and C in Fig. 91 are alike, one pattern will answer for the two. Therefore let 1 7 8 11 14 in Fig. 97 be a reproduction of the branch C in Fig. 91. Now take a tracing of *a b c* in Fig. 92 and place it as shown by 11′ 11 8 in Fig. 97; also take a tracing of the half section E and the quarter section D in Fig. 91 and place them as shown respectively by 1 4′ 7 and 11 11′ 14 in Fig. 97. Now divide the two lower profiles 8 11 and 11′ 14 each into 3 equal parts, and the upper profile 7 4′ 1 into 6 equal parts as shown by the small figures 8 to 11′, 11′ to 14 and 1 to 7. From these points, at right angles to the various base lines, draw lines, intersecting the base lines as shown by similar numbers. Draw solid and dotted lines as shown, and construct the sections on solid lines as shown in Fig. 98 and the sections on dotted lines as shown in Fig. 99 in precisely the same manner as described in connection with Figs. 94 and 95.

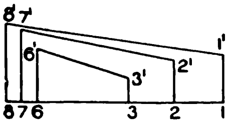


Fig. 94.

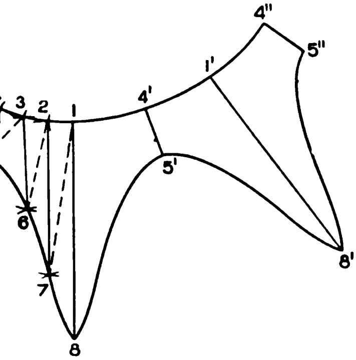


Fig. 96.

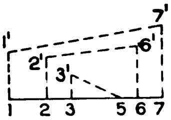


Fig. 95.

In Fig. 100 is shown the pattern shape (to which laps must be allowed for riveting) obtained as was the development of Fig. 96. First draw the vertical line 1 14, Fig. 100, equal to 1 14 in Fig. 97. Then use alternately as radii, first the divisions in 1 4′ 7 in Fig. 97, the proper slant line in Figs. 98 and 99 and the divisions in 11′ 14 until the line 4 11, Fig. 100, is obtained. Starting from the point 11 use as radii in their regular order the distances marked off between 11′ and 8, Fig. 97, then the proper slant lines in Figs. 98 and 99, the distances shown in the semicircle, 1 4′ 7, Fig. 97, until the line 7 8, Fig. 100, is drawn equal to 7 8, in Fig. 97. Then

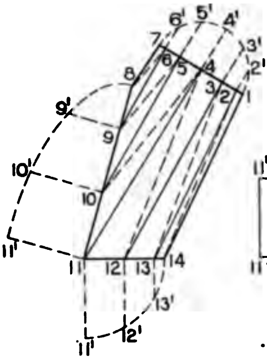


Fig. 97.

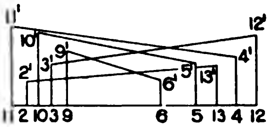


Fig. 98.

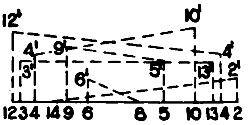


Fig. 99.

1 7 8 11 14, Fig. 100, will be the half pattern. If the pattern is desired in one piece trace 1 7′ 8′ 11′ 14 opposite the line 1 14 as shown.

In Fig. 101 is shown a perspective view of a two-branch fork oval to round, commonly used as breeching for two boilers. As

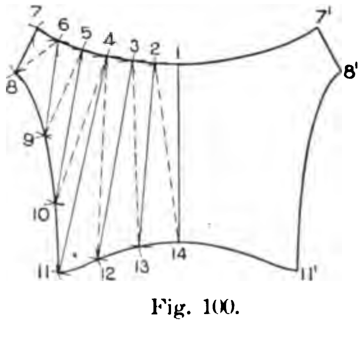


Fig. 100.

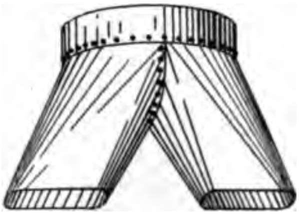


Fig. 101.

both halves of the fork are symmetrical the pattern for one will answer for the other.

While the side elevation shown in Fig. 102 is drawn complete, it is only necessary in practice, to draw one half as follows, and then, if desired, the other half elevation can be traced opposite to the center line E J. First draw J B, 1½ inches, equal to the half diameter of the outlet, and the vertical center height J V, 2¼ inches. Establish the height of the joint J E one inch, and the desired projection V D on the base line 1¼ inches. Draw the length of the inlet D C 2¾ inches, and draw a line from C to B and D to E. Draw a similar figure opposite the line J E, and A B C D E F G shows the side elevation of the fork. In their proper position below A B draw the sections M and N whose semicircular ends are struck from *a b c* and *d* with radii equal to ½ inch. Now draw an end elevation in which the true section on J E is obtained. Draw the center line *f e* and extend the lines A B and G C in elevation as A P and G S. Take the half diameter L J and place it on either side of *e f* as shown by O P. In a similar manner take the half diameter of the section N as *d i* and place it on either side of *e f* as shown by R S. Then O P S R shows the end elevation. Draw E T intersecting *e f* at T. Now draw the curve O T P, which in this case is struck from the center U, being obtained by bisecting the line O T. It should be understood that the curve O T P, which represents the true section on J E, can be made any desired shape, but when once drawn, represents a fixed line.

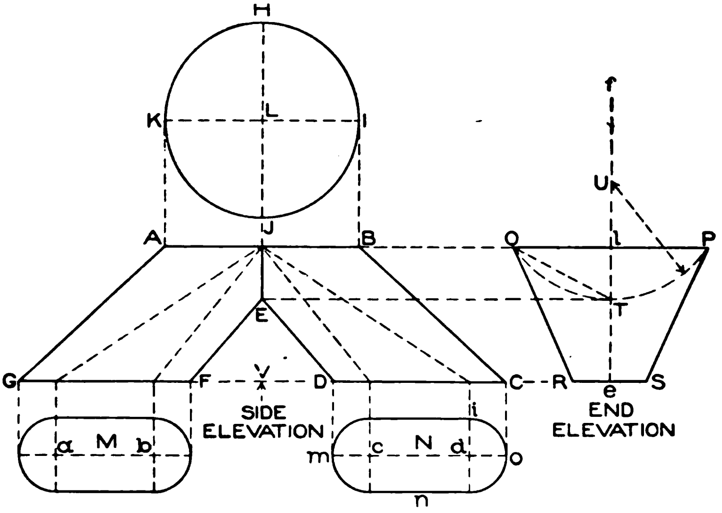


Fig. 102.

The pattern will be developed by triangulation, for whicl diagrams of sections must be obtained from which to obtain measurements. These sections are obtained as follows: In Fig. 10 1 4 5 12 13 is a reproduction of J B C D E, Fig. 102. Reproduc the quarter profile H L I, the half profile O T, and the half profil *m n o* as shown by 1′ 1 4, 1″ 13 1 and 12 9′ 8′ 5 in Fig. 103. Divide the round ends in *a* each into 3 parts and the profiles *b* and *c* also each into 3 spaces, as shown by the figures. Drop lines from these figures at right angles to the base lines from 1 to 15 as shown and draw solid and dotted lines in the usual manner. While in some of the previous problems only dotted lines were drawn, we have drawn both solid and dotted lines in this case, in order avoid a confusion of sections. A diagram of sections on solid li in Fig. 103 is shown in Fig. 104, the figures in both correspo ing; while Fig. 105 shows the true sections on dotted lines. method of obtaining these sections has been described in connec with other problems.

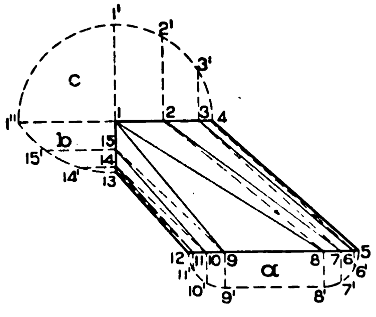


Fig. 103.

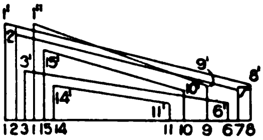


Fig. 104.

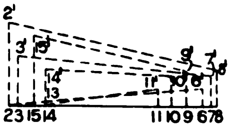


Fig. 105.

For the pattern draw any vertical line as 4 5, Fig. 106, to 4 5 in Fig. 103. Then with 5 6′, Fig. 103, as [illegible] Fig. 106 as center draw the arc 6, intersecting it b from 4 as center and 4 6′, Fig. 105, as radius. T Fig. 103, as radius, and 4 in Fig. 106 as center, d intersecting it by an arc struck from 6 a [illegible] 104 as radius. Proceed in this manner [illegible] first the divisions in *a* in Fig. 103, t 105; the divisions in *c* in Fig. 103, the

104, until the line 1 8, Fig. 106, is obtained. Now using 8 as center and 8' 9', Fig. 103, as radius draw the arc 9 in Fig. 106, intersecting it by an arc struck from 1 as center and 1" 9', Fig. 104, as radius. Then starting at 1 in Fig. 106 use alternately as radii, first the divisions in *b* in Fig. 103, then the slant lines in Fig. 105, the divisions in *a* in Fig. 103, then the length of the slant lines in Fig. 104 until the line 12 13 is obtained in Fig. 106, which equals 12 13 in Fig. 103. Trace a line through points thus obtained in Fig. 106, then will 4 1 13 12 9 8 5 be the half pattern. If the pattern is desired in one piece, trace this half opposite the line 4 5 as shown by 1' 13' 12' 9' 8', allowing laps for riveting.

In Fig. 107 is shown a perspective view of a tapering flange around a cylinder passing through an inclined roof, the flange being rectangular on the roof line. The problem will be developed by triangulation, a plan and elevation first being required as shown in Fig. 108.

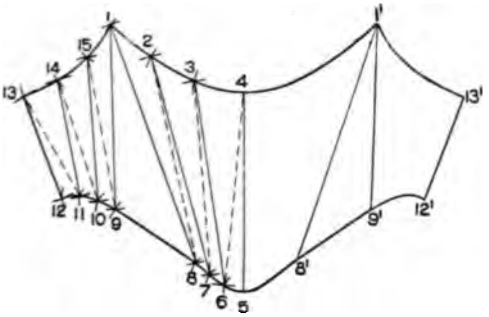


Fig. 106.

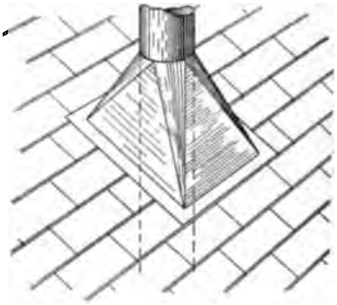


Fig. 107.

First draw the angle of the roof A B at an angle of 45°, through which draw a center line C D. From the roof line A B on the center line set off *a b* equal to 4 inches and through *b* draw the horizontal line E F, making B F and B E each one inch. Through *d* on the center line draw the horizontal line G H, making *d* H and *d* G each two inches. From H and G erect perpendiculars intersecting the roof line at K and L. Then draw lines from E to K and F to L, completing the elevation. Construct the square in plan making the four sides equal to G H. Bisect H I and draw the center line *c c* intersecting the vertical center at *d'*. Then with radius equal to *b* F or *b* E in elevation and *d'* in plan as center, draw the circle 1 4 7 4′ representing the horizontal section on E F in elevation, while G H I J is the horizontal section on K L in elevation. As the circle in plan is in the center of the square making the two halves symmetrical it is only necessary to divide the semicircle into equal spaces as shown from 1 to 7 and draw lines

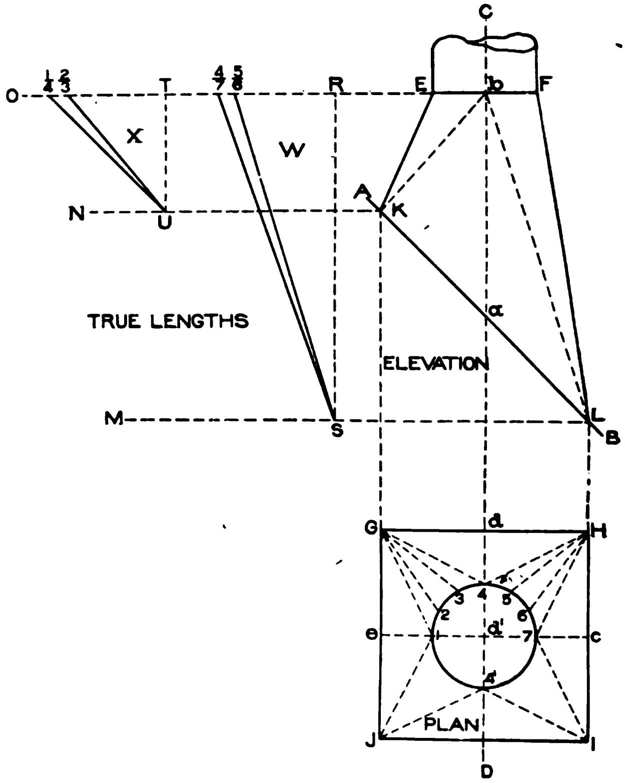


Fig. 108.

from 1, 2, 3 and 4 to G, and 4, 5, 6 and 7 to H. Then will the lines in 1 G 4 and 4 H 7 represent the bases of triangles which will be constructed, whose altitudes are shown respectively by the vertical heights in K E and L F in elevation. Therefore draw horizontal lines through E F, K, and L as shown by F O, K N, and L M. From any point as R and T on F O, draw the perpendiculars R S and T U respectively, meeting the horizontal lines drawn from L and K. Now take the various lengths in plan as G1, G2, G3, and

G4 and place them on the line F O as shown by T1, T2, T3 and T4, from which points draw lines to U which will represent the true lengths on similar lines in plan. In similar manner take the distances in plan from H to 4, to 5, to 6, to 7, and place them on the line F O, from R to 4, to 5, to 6, to 7, from which points draw lines to S which represent the true lengths on similar lines in plan.

For the pattern take the distance F L in elevation and place it on the vertical line 7′ L in Fig. 109. At right angles to 7′ L draw L S equal to e H or e I in plan, Fig. 108. Draw the dotted line from 7′ to S in Fig. 109, which should be equal to S 7 in W in Fig. 108. Now with radii equal to S $\frac{4}{7}$, and S $\frac{5}{6}$ and S, Fig. 109, as center, draw the arcs indicated by similar numbers. The dividers should equal the spaces in the semicircle in plan in Fig. 108, and starting at 7′ in Fig. 109, step from arc to arc of corresponding numbers as shown by 6′, 5′, 4′. Draw a dotted line from 4′ to S. Then using S as center and L K in elevation, Fig. 108, as radius, describe the arc U in Fig. 109, intersecting it by an arc struck from 4′ as center and U 4, Fig. 108, as radius. Now using U $\frac{1}{4}$, and U $\frac{2}{3}$ in X as radii, and U, Fig. 109, as center, describe arcs having similar numbers. Again set the dividers equal to the spaces in plan in Fig. 108, and starting from 4′ in Fig. 109 step to corresponding numbered arcs as shown by 3′, 2′, 1′.

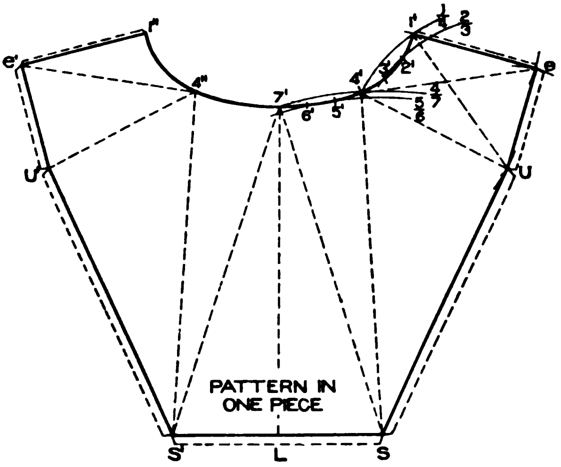


Fig. 109.

Draw a dotted line from 4′ to U to 1′. With K E in elevation, Fig. 108, as radius, and 1′ in Fig. 109 as center, describe the arc *e* intersecting it by an arc struck from U as center and G *e* in plan in Fig. 108 as radius. Draw a line connecting S, U, *e*, and 1′. 7′ 4′ 1′ *e* U S L 7′ shows the half pattern, which can be traced opposite the line 7′ L to complete the full pattern as shown by 7′ 4″ 1″ *e′* U′ S′ L.

One of the difficult problems often encountered by the sheet metal worker is that of a cylinder joining a cone furnace top at any angle. The following problem shows the principle to be applied, no matter what size the furnace top has, or what size pipe is used, or at what angle the pipe is placed in plan or elevation, the principles being applicable under any conditions.

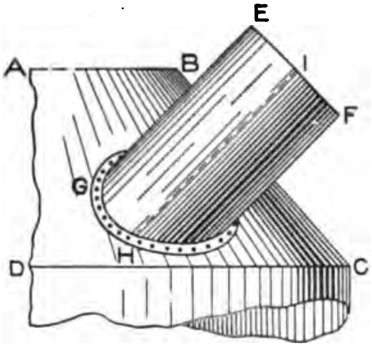


Fig. 110.

Fig. 110 shows a view of a cylinder intersecting a conical furnace top, the pipe being placed to one side of the center of the top. A B C D represents a portion of the conical top, intersected by the cylinder E F G H, the side of the cylinder H I to intersect at a given point on the conical top as at H. This problem presents an interesting study in projections, intersections, and development, to which close attention should be given.

In Fig. 111 first draw the center line A X. Then draw the half elevation A B C D, making A B $1\frac{5}{8}$ inches, C D $3\frac{1}{2}$ inches and the vertical height A D $2\frac{1}{8}$ inches. Draw the line from B to C. Directly below C D draw the one-quarter plan using Z as center, as shown by Z C^1 D^1 and in line with A B of the elevation draw the quarter plan of the top as Z B^1 A^1. Let *a* in the elevation represent the desired distance that the side of the cylinder is to meet the cone above the base line as H in Fig. 110. From *a*, parallel to C D in Fig. 111, draw *a b*. Then from *a* drop a vertical line intersecting the line Z C^1 in plan at *a′*. Then using Z as center and Z *a′* as radius, describe the quarter circle *a′ b′*. Z *a′ b′*

in plan represents the true section on the horizontal plane *a b* in elevation. Now locate the point where the side of the cylinder as H in Fig. 110 shall meet the arc *a' b'* in plan, Fig. 111, as shown

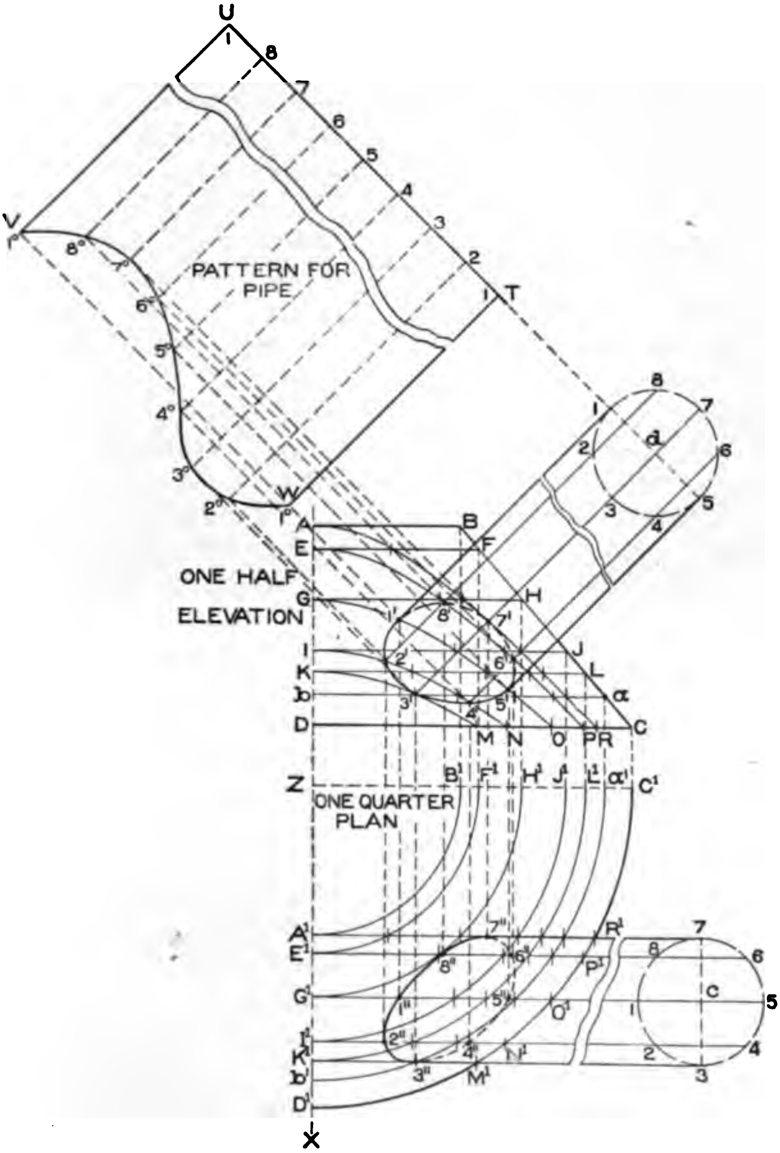


Fig. 111.

at 3″. Through 3″ draw the horizontal line intersecting the center line at K^1, the outer arc at M^1 and extend it indefinitely to 3. From 3 erect the perpendicular equal to the diameter of the cylinder, or $1\frac{5}{8}$ inches, bisect it and obtain the center *c*. Using *c* as center with *c* 7 as radius, describe the profile of the cylinder as shown, and divide it into equal parts from 1 to 8. From these points draw lines parallel to 3 K^1, intersecting the outer arc D^1 C^1 at N^1 O^1 P^1 R^1 and the center line Z X at I^1, G^1, E^1, A^1. With Z as center and the various intersections from K^1 to A^1 as radii, describe the arcs K^1 L^1, I^1 J^1, G^1 H^1, E^1 F^1, and A^1 B^1. From the intersection B^1, F^1, H^1, J^1, L^1 erect vertical lines into the elevation intersecting the side of the cone B C as shown by similar letters B F H J L. From these points draw horizontal lines through the elevation as shown respectively by A B, E F, G H, I J, and K L. These lines represent a series of horizontal planes, shown in plan by similar letters. For example, the arc E^1 F^1 in plan represents the true section on the line E F in elevation, while the arc G^1 H^1 is the true section on the line G H in elevation, etc.

The next step is to construct sections of the cone as it would appear, if cut by the lines shown in plan by K^1 M^1, I^1 N^1, G^1 O^1, E^1 P^1, and A^1 R^1. To obtain the section of the cone in elevation on the line A^1 R^1 in plan, proceed as follows: At right angles to the line A^1 R^1 and from the intersections on the various arcs, draw lines upward (not shown) intersecting similar planes in elevation corresponding to the arcs in plan. A line traced through intersections thus obtained in elevation as shown from A to R, will be the true section on the line A^1 R^1 in plan. For example, the line K^1 M^1 of the cylinder intersects the arcs at K^1 3″ and M^1 respectively. From these intersections, erect vertical lines intersecting K L, *b a*, and D C in elevation at K, 3′, and M respectively. Trace a curve through these points, then will K 3′ M be the section of the cone if cut on the line K^1 M^1 in plan. In similar manner obtain the other sections. Thus the section line E P, G O, and I N in elevation, represent respectively the sections if cut on the lines E^1 P^1, G^1 O^1, and I^1 N^1 in plan. Now from the given point 3″ in plan erect a line which must meet the intersection of the plane *b a* and section K M in elevation at 3′. From 3′ at its desired angle, in this case 45°, draw the line 3′ 7. At any point as *d* at right angles to 3′ 7 draw the line 1 5 through *d*, making *d* 5 and *d* 1 each equal to half the diameter of the cylinder shown in plan. With *d* 5 as radius and *d* as center draw the profile of the cylinder in elevation, and divide it into the same number of parts as shown in C in plan, being careful to allow the circle *d* in elevation to make a quarter turn, bringing the number 1 to the top as shown.

The next operation is to obtain the miter line or line of joint between the cylinder and cone in elevation. By referring to the plan it will be seen that the point 7 in the profile *c* lies in the plane of the section A^1 R^1. Then a line from the point 7 in the profile *d* in elevation, drawn parallel to the lines of the cylinder, must cut the section A R which corresponds to the plane A^1 R^1 in plan as shown by 7′ in elevation. The points 6 and 8 in the profile *c* in plan, are in the plane at the section E^1 P^1, then must the corresponding points 6 and 8 in the profile *d* in elevation, intersect the section E P as shown by 6′ and 8′. As the points 1 5, 2 4, and 3 in the profile *c* in plan, are in the planes of the sections G^1 O^1, I^1 N^1, and K^1 M^1 respectively, the corresponding points 1 5, 2 4, and 3 in the profile *d* in elevation must intersect the sections G O, I N, and K M respectively at points 1′ 5′, 2′ 4′, and 3′ as shown. Trace a line through these points, which will show the line of intersection between the cone and cylinder.

For the pattern for the cylinder, proceed as follows: At right angles to the line of the cylinder in elevation, draw the line T U upon which place the stretchout of the profile *d* as shown by similar figures on T U. In this case the seam of the pipe has been placed at 1 in *d*. Should the seam be desired at 3, 5 or 7, lay off the stretchout on T U starting with any of the given numbers. At right angles to U T from the small figures 1 to 1 draw lines which intersect with lines drawn from similar numbered intersections in the miter line in elevation at right angles to 1′ 1, resulting in the intersections 1 to 5° to 1 in the pattern. Trace a line through points thus obtained, then will U V W T be the development for the cylinder to which laps must be allowed for riveting to the cone as shown in Fig. 110 and seaming the joint T′ W in pattern in Fig. 111.

While the pattern for the cone is obtained the same as in ordinary flaring ware, the method will be described for obtaining the pattern for the opening to be cut into the cone. Before this can be done a plan view of the intersection between the pipe and cone must first be obtained as follows: From the various intersections $1'$ to $8'$ in elevation drop vertical lines intersecting lines drawn from similar numbers in the profile *c* in plan, thus obtaining the intersections $1''$ to $8''$ through which a line is traced which is the desired plan view.

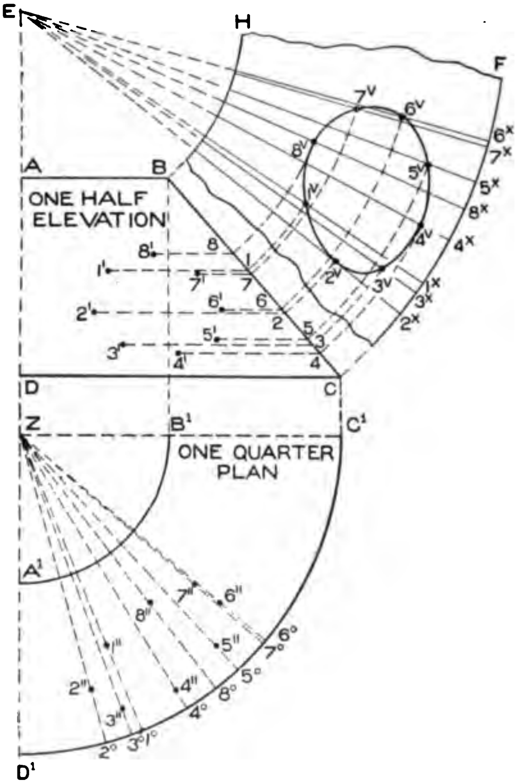


Fig. 112.

For the pattern for the opening in the cone, the outline of the half elevation and one-quarter plan with the various points of intersections both in plan and elevation in Fig. 112 is a reproduction of similar parts in Fig. 111, and has been transferred to avoid a confusion of lines which would otherwise occur in obtaining the pattern. Parallel to D C in Fig. 112 from the various intersections $1'$ to $8'$ draw lines intersecting the side of the cone B C from 1 to 8. Through the various intersections $1''$ to $8''$ in plan from the apex Z draw lines intersecting the outer curve from 1° to 8° as shown. Extend the line C B in elevation until it meets the center line D A extended at E. Then using E as center, with E C and E B as radii draw the arcs C F and B H respectively. At any point as 2^{x} on the arc C F lay off the stretchout of the various points on D^1 C^1 in plan from 2° to 6° as shown by similar figures on C F as shown from 2^x to 6^x. From these points draw radial lines to the apex E, and intersect them by arcs struck from E as center whose radii are equal to the various intersections on B C having similar numbers. Thus arc 4 intersects radial line 4^x at 4^v; arcs 3, 5, and 2 intersect radial lines 3^x, 5^x, and 2^x at 3^v, 5^v, and 2^v, and so on. Trace a line through points thus obtained as shown from 1^v to 8^v which is the desired shape. If a flange is desired to connect with the cylinder, a lap must be allowed along the inside of the pattern.

COPPERSMITH'S PROBLEMS.

In the five problems which will follow, particular attention is given to problems arising in the coppersmith's trade. While all the previous problems given in the course can be used by the coppersmith in the development of the patterns where similar shapes are desired, the copper worker, as a rule, deals mostly with hammered surfaces, for which flaring patterns are required. The principles which will follow, for obtaining the blanks or patterns for the various pieces to be hammered, are applicable to any size or shape of raised work. The copper worker's largest work occurs in the form of brewing kettles, which are made in various shapes, to suit the designs of the different architects who design the work. In hammering large brewing kettles of heavy copper plate, the pieces are developed, hammered, and fitted in the shop, then set together in the building, rope and tackle being used to handle the various sections for hammering, as well as in construction at the building. While much depends upon the skill the workman has with the hammer, still more depends upon the technical knowledge in laying out the patterns.

In all work of this kind the patterns are but approximate, but no matter what size or shape the work has, the principles contained in the following problems are applicable to all conditions.

In Fig. 113 is shown a perspective of a sphere which is to be constructed of horizontal sections as shown in Fig. 114, in which for practice draw the center line A B, on which, using *a* as center, and with radius equal to $2\frac{1}{4}$ inches, describe the elevation of the sphere B C D E. Divide the quarter circle D C into as many spaces as the hemi-sphere is to have sections, as shown by C F G D. From these points draw horizontal lines through the elevation, as stood that no hammering is done to that part shown from 3 to 4. The portion shown from 3 to 1′ is stretched to meet the required profile 3 2 1, while the lower part 4 to 6′ is raised to conform with the lower curve 4 5 6. Therefore, knowing that the points 3 and 4 are fixed points, then from either of these, in this case point 4,

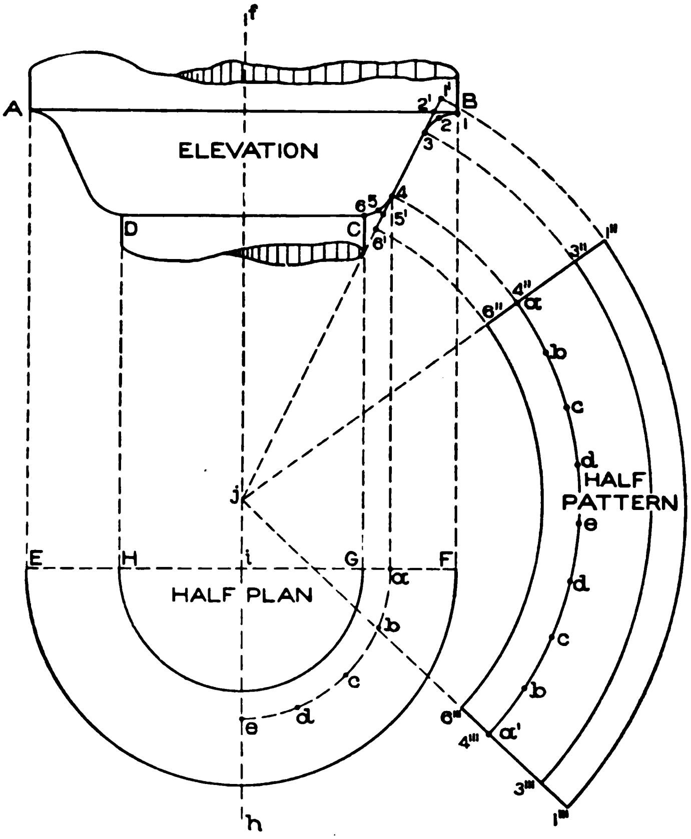


Fig. 116.

drop a vertical line intersecting the center line E F in plan at *a*. Then with *i* as center and *i a* as radius, describe the quarter circle *a e*, and space it into equal parts as shown by *a*, *b*, *c*, *d*, *e*, which represent the measuring line in plan on the point 4 in elevation. Using *j* as center, and *j* 6′, *j* 4, *j* 3 and *j* 1′ as radii, draw the arcs 1″-1‴, 3″-3‴, 4″-4‴ and 6″-6‴ as shown. From 1″ draw a radial line to *j* intersecting all the arcs as shown. Now starting at 4″ step off on the arc 4″-4‴ twice the stretchout of the quarter circle *a e* as shown by similar letters *a* to *e* to *a′* in pattern. From *j* draw a line through *a′* intersecting all of the arcs as shown. 1″-1‴-6‴-6″ shows the half pattern for the ogee.

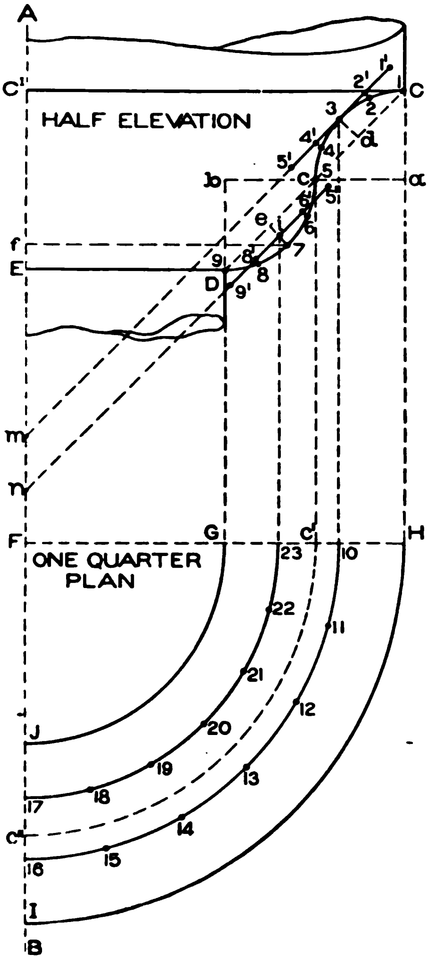


Fig. 117.

While in the previous problem the greater part of the ogee was flared, occasion may arise where the ogee is composed of two quarter circles struck from centers as shown in Fig. 117. First draw the center line A B, then draw the half diameter of the top C¹ C equal to 3¼ inches and the half diameter E D 1¾ inches. Make the vertical height of the ogee 1½ inches, through the center of which draw the horizontal line *a b*. From C and D draw vertical lines intersecting the horizontal line *a b*, at *a* and *b* respectively. Then using *a* and *b* as centers with radii equal respectively to *a* C and *b* D draw the quarter circles shown completing the ogee. In the quarter plan below which is struck from the center F, G J and H I are sections respectively on D E and C C¹ in elevation. The methods of obtaining the patterns in this case are slightly different than those employed in the previous problems. The upper curve shown from C to *c* will have to be stretched, while the lower curve shown from *c* to D will have to be raised. Therefore in the stretchout of the pattern of the upper part from 1′ to 3 and 3 to 5′ the edges must be stretched so as to obtain more material to allow the metal to increase in diameter and conform to the desired shape shown from 1 to 3 and 3 to 5. In the lower curve the opposite method must be employed. While in the upper curve the edges had to be stretched to increase the diameters, in the lower curve the edges must be drawn in by means of raising, to decrease the diameter, because the diameters to the points 5″ and 9′ are greater than to points *c* and *d*.

To obtain the pattern for the upper curve C *c* which must be stretched, draw a line from C to *c*; bisect it and obtain *d*, from which erect the perpendicular *d* 3 intersecting the curve at 3. Through 3 draw a line parallel to C *c* intersecting the center line A B at *m*. Now divide the curve C *c* into equal spaces as shown from 1 to 5 and starting from the point 3 set off on the line just drawn on either side of 3 the stretchout shown from 3 to 1′ and 3 to 5′. 1′ 5′ shows the amount of material required to form the curve C *c*. In this case 3 represents the stationary point of the blank on which the pattern will be measured. Therefore from 3 drop a vertical line intersecting the line F H at 10. Then using F as center and F 10 as radius, describe the arc 10 16, and divide it into equal spaces as shown from 10 to 16. Now with radii equal to *m* 5′, *m* 3 and *m* 1′, Fig. 117, and with *m* in Fig. 118 as center, describe the arcs 5 5′, 3 3′ and 1 1′. Draw the radial line *m* 1 intersecting the two inner arcs at 3 and 5. As the arc 3 3′ represents the stationary point 3 in elevation in Fig. 117, then set the dividers equal to the spaces 10 16 in plan and step off similar spaces in Fig. 118 on the arc 3 3′, starting at 3 as shown by similar numbers 16 to 10. Through 10 draw a line to the apex *m*, intersecting the inner curve at 5′ and the outer curve at 1′. 1 1′ 5′ 5 is the quarter pattern for the upper curve or half of the ogee, to which laps must be allowed for riveting and brazing.

For the pattern for the lower curve in elevation in Fig. 117 draw a line from *c* to D; bisect it at *e* and from *e* erect a perpendicular intersecting the curve at 7. From 7 draw a horizontal line intersecting the center line at *f*. Now the rule to be followed in "raising" is as follows: Divide the distance from *e* to 7 into as many parts, as the half diameter F 7 is equal to inches. In this case 7 *f* equals 2¼ inches; (any fraction up to the ½ inch is not taken into consideration, but over ½ inch one is added). Therefore for 2¼ inches use 2. Then divide the distance from *e* to 7 into two parts as shown at *i* and through *i* parallel to *c* D draw a line as shown intersecting the center line at N. Now divide the curve *c* to D into equal spaces as shown by the figures 5 to 9. Let off on either side of *i* the stretchout from 5 to 9 as shown from 5″ to

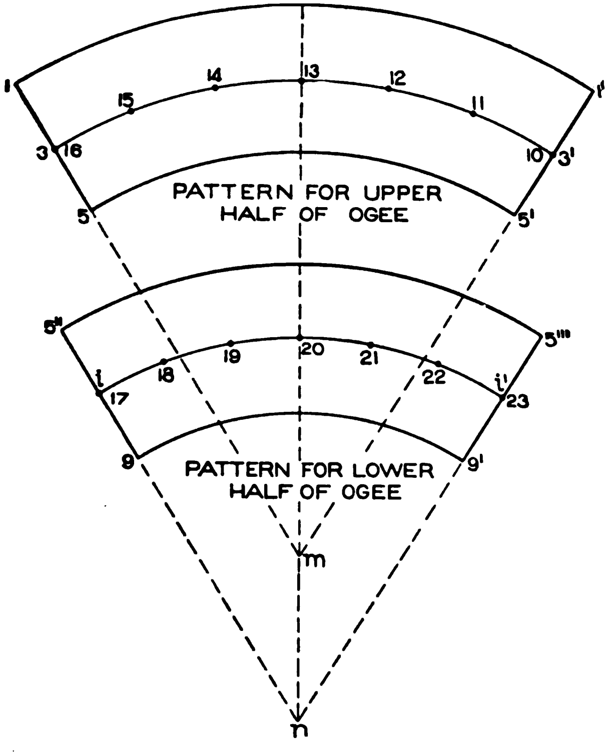


Fig. 118.

9′. From *i* drop a vertical line intersecting F H in plan at 23. Then using F as center draw the arc 23 17 as shown, which represents the measuring line in plan on *i* in the stretchout.

The student may naturally ask, why is *i* taken as the measuring line in plan, when it is not a stationary point, for when "raising" *i* will be bulged outward with the raising hammer until it meets the point 7. In bulging the metal outward, the surface at *i* stretches as much as the difference between the diameter at *i* and

7. In other words, if the measuring point were taken on 7 it would be found that after the mould was "raised" the diameter would be too great. But by using the rule of dividing e 7 into as many parts as there are inches in f 7 the diameter will be accurate while this rule is but approximate. In this case e 7 has only been divided into two equal parts, leaving but one point in which a line would be drawn through parallel to c D. Let us suppose that the semi-diameter 7 f is equal to eleven inches. Then the space from e to 7 would be divided into just so many parts, *and through the first part nearest the cove* the line would be drawn parallel to c D and used as we have used i. Now with radii equal to $n\ 9'$, $n\ i$, and $n\ 5''$ and n in Fig. 118 as center, describe the arcs $5''\ 5'''\ i\ i'$ and $9\ 9'$. From any point as $5''$ draw a line to n intersecting all the arcs shown. Now take the stretchout from 17 to 23 in plan, Fig. 117, and starting from 17 in Fig. 118 mark off equivalent distances on the arc $i\ i'$ as shown. Draw a line through 23 to the apex n, intersecting the inner and outer arcs at $9'$ and $5'''$. Then will $9\ 5''\ 5'''\ 9'$ be the greater pattern for the lower part of the ogee.

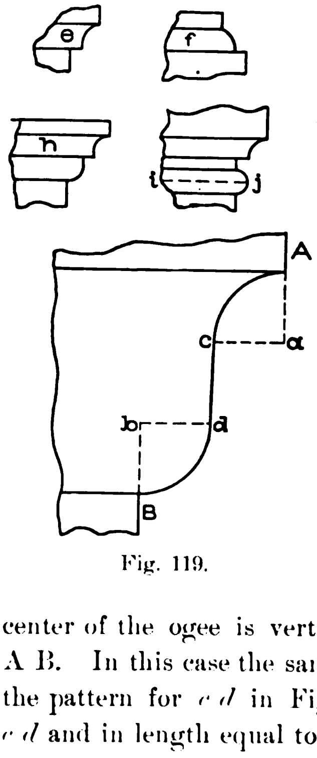


Fig. 119.

Another case may arise where the center of the ogee is vertical as shown from c to d in Fig. 119 in A B. In this case the same principles are applied as in Fig. 117; the pattern for $c\ d$ in Fig. 119 being a straight strip as high as $c\ d$ and in length equal to the quarter circumference $c'\ c''$ in plan in Fig. 117 which is the section on c in elevation. These rules are applicable to any form of mould as shown in Fig. 119, by e, f, h, and j. The bead i in j would be made in two pieces with a seam at i as shown by the dotted line, using the same method as explained in connection with c D in elevation in Fig. 117.

The coppersmith has often occasion to lay out the patterns for curved elbows. While the sheet metal worker lays them out in pieces, the coppersmith's work must form a curve as shown in Fig. 120 which represents a curved elbow of 45°.

In Fig. 121 is shown how an elbow is laid out having 90°, similar principles being required for any degree of elbow. First draw the side elevation of the elbow as shown by A B C D, making the radius E B equal to 4½ inches and the diameter B C 2 inches. Bisect C B at K. Then with E as center and E K as radius draw the arc K J representing the seam at the sides. Draw the front view in its proper position as F G H, through which draw the center line F I representing the seam at back and front, thus making the elbow in four pieces. Directly below C B draw

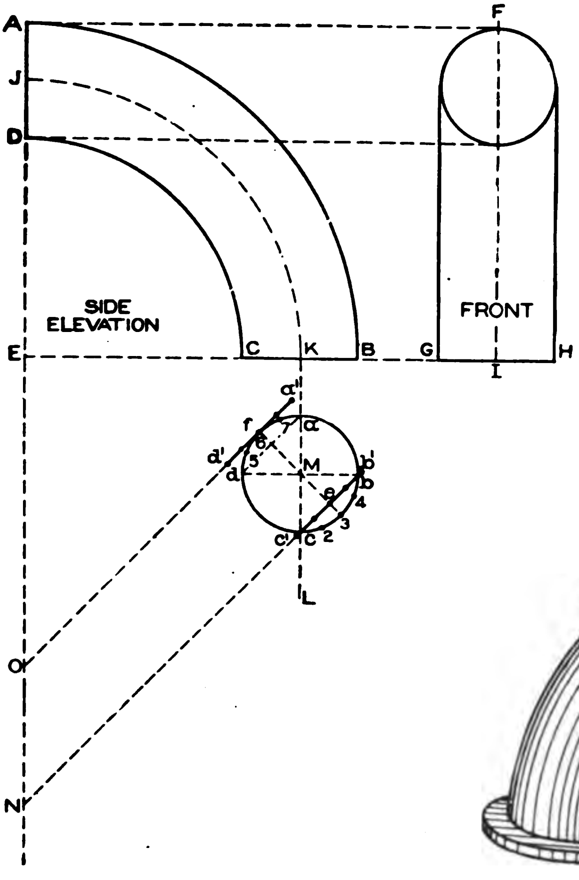


Fig. 121.

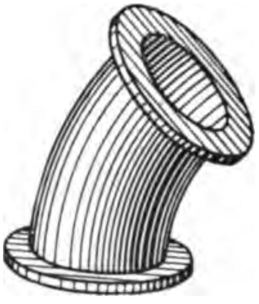


Fig. 120.

the section of the elbow as shown by *a b c d* struck from M as center. Through M draw the diameters *b d* and *a c*. The inner curve of the elbow *a d c* in plan will be stretched, while the outer curve *a b c* in plan will be raised. Through M draw the diagonal 3 6 intersecting the circle at 3 and *f* respectively. Now draw *a d;* through *f* parallel to *a d* draw a line intersecting the center line A E extended at O. On either side of *f* place the stretchout of 6 *a* and 6 *d* as shown by *f a′* and *f d′*. Then with radii equal to O *d′* and O *a′* and with O on the line A B, Fig. 122, as center describe the arcs *d d* and *a a*. Make the length of *d d* equal to the inner curve D C in Fig. 121. From *a* and *d* in Fig. 122 draw lines to the apex O extending them to meet the outer curve at *a* and *a*. Then will *a d d a* be the half pattern for the inner portion of the elbow for two sides. The radius for the pattern for the outer curve is shown in Fig. 121 by N *c′*, N *b′*, placing the

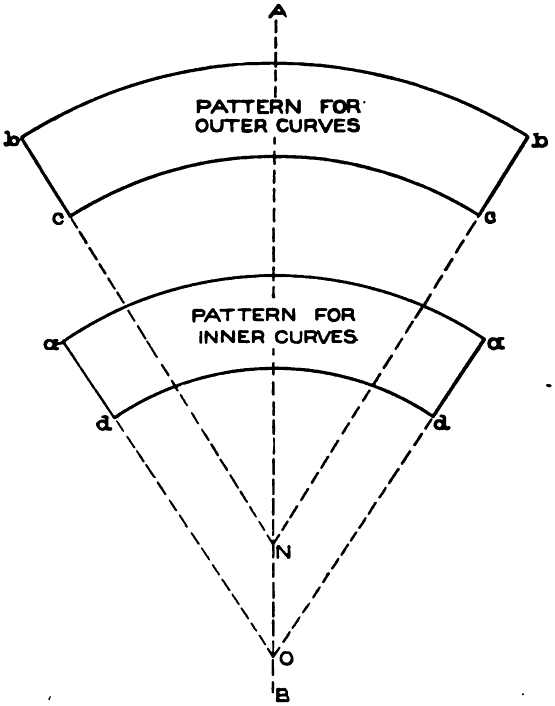


Fig. 122.

stretchout of the curve on either side of the point *e*. *b b c c* in Fig. 122 shows the pattern for the outer curve, the length *b b* being obtained from A B in elevation in Fig. 121.

In work of this kind the patterns are made a little longer, to allow for trimming after the elbow is brazed together. Laps must be allowed on all patterns for brazing.

Fig. 123 shows a perspective view of a brewing kettle, made in horizontal sections and riveted. The same principles which were employed for obtaining the patterns for a sphere in Fig. 114 are applicable to this problem. Thus in Fig. 124, let A B C represent a full section of a brewing kettle as required according to architect's design. Through the middle of the section draw the center line D E. Now divide the half section B to C into as many parts as the kettle is to have pieces as shown by *c*, *d*, *e*, *f*. From these small letters draw horizontal lines through the section, as shown by *c* A, *d d'*, *e e'*, and *f f''* and in its proper position below the section, draw the plan views on each of these horizontal lines in elevation, excepting *d' d*, as shown respectively by I F G H, *e'' e'''* and *f''' f''''*, all struck from the center *a*. Now through the points *c d* draw a line which if extended would meet the center line. Then this intersection would be the center with which to draw the arcs *c c'* and *d d''*; the flange *c b* would be added to the pattern as shown by *b'*. The stretchout for this pattern 1^1 would be obtained from the curved line F G H I in plan and stepped off on the outer arc *c c'*. In similar manner through *d e*, *e f*, and *f* C draw the lines intersecting the center line D E at K, L, and C. Then using the points as center, describe the patterns 2^1, and 3^1, and the full circle 4^1.

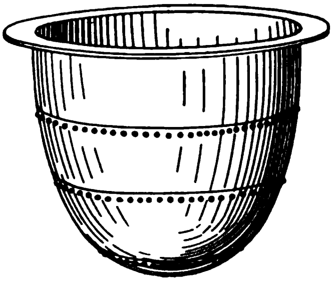


Fig. 123.

The stretchout for the patterns 2^1 and 3^1 is obtained from the circle *e'' e'''* in plan and placed on the inner curve of the pattern 2^1, and on the outer curve of the pattern 3^1. If desired the stretchout could be taken from *f''' f''''* in plan, and placed on the inner curve of 3^1 which would make the pattern similar as before.

In large kettles of this kind, the length of the pattern is guided by the size of the sheets in stock, and if it was desired that each ring was to be made in 8 parts then the respective circle in plan from which the stretchout is taken would be divided into 8 parts, and one of these parts transferred to the patterns, to which laps must be allowed for seaming and riveting.

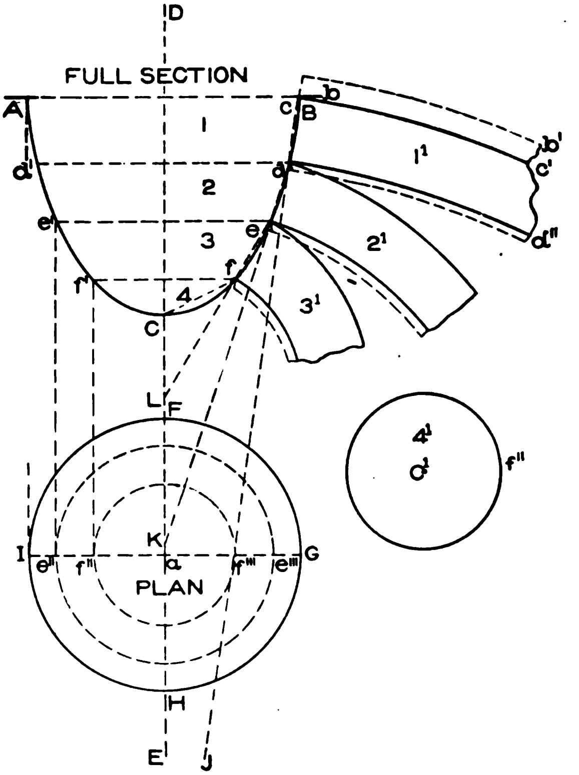


Fig. 124.

PROBLEMS FOR WORKERS IN HEAVY METAL.

While all of the problems given in this course are applicable to developments in heavy metal as well as in that of lighter gauge, the following problems relate to those forms made from boiler plate.

When using metal of heavier gauge than number 20, for pipes, elbows, or any other work, it is necessary to have the exact inside diameter. It is customary in all shops working the heavier metal, to add a certain amount to the stretchout to make up for the loss incurred in bending, in order that the inside diameter of the article (pipe, stack, or boiler shell) may be kept to a uniform and desired size. This amount varies according to different practice of workmen, some of whom allow 7 times the thickness of the metal used, while others add but 3 times the thickness. Theoretically the amount is 3.1416 times the thickness of the metal.

For example, suppose a boiler shell or stack is to be made 48 inches in diameter out of $\frac{1}{2}$-inch thick metal. If this shell is to measure 48 inches on the inside, add the thickness of the metal, which is $\frac{1}{2}$ inch, making $48\frac{1}{2}$ inches. Multiply this by 3.1416 and the result will be the width of the sheet. If, on the other hand, the outside diameter is to measure 48 inches, subtract the thickness of the metal, which would give $47\frac{1}{2}$ inches and multiply that by 3.1416 which would give the proper width of the sheet. It is well to remember that no matter what the thickness of the plate may be, if it is not added, the diameter of the finished article will not be large enough; for where no account is taken of the thickness of the metal, the diameter will measure from the center of the thickness of the sheet. While this rule is theoretically correct there is always a certain amount of material lost during the forming operations. It is, therefore, considered the best practice to use seven times the thickness of the metal in question. The circumference for a stack 48 inches in diameter inside using $\frac{1}{2}$ inch metal would be, on this principle, $3.1416 \times 48 + (7 \times \frac{1}{2})$ to which laps would have to be allowed for riveting. Where the stack has both diameters equal a butt joint is usually employed with a collar as shown at either *a* or *b* in Fig. 125, but where one end of the stack is to fit into the other, a tapering pattern must be obtained which will be described as we proceed.

In putting up large boiler stacks it is usual to finish at the top with a moulded cap, and while the method of obtaining the patterns is similar to parallel line developments, the method of developing such a pattern will be given showing how the holes are punched for a butt joint.

In Fig. 126 a view of the moulded cap on a stack is shown. On a large size stack the cap is often divided into as many as 32 pieces. If the stack is to be made in horizontal sections the rules given in the problems on coppersmithing apply. While in obtaining the patterns for a cap in vertical sections, the plan is usually divided into 16 to 32 sides, according to the size of the stack; we have shown in Fig. 127 a quarter plan so spaced as to give 8 sides to the full circle. This has been done to make each step distinct, the same principles being applied no matter how many sides the plan has.

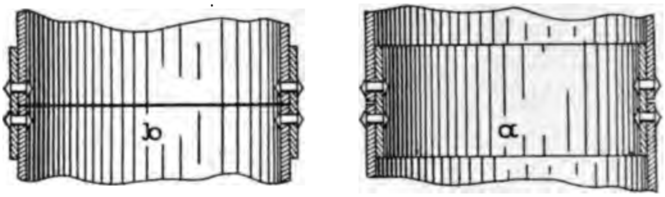


Fig. 125.

First draw the center line A B and with any point as C with radius equal to $4\frac{1}{2}$ inches draw the quadrant D E. Now tangent to D and E, draw the line D F and E G, and at an angle of 45°, tangent to the curve at Y, draw G F intersecting the previous lines drawn at G and F. C D F G E shows the plan view of the extreme outline of the cap. Directly above the plan draw a half section of the cap, the curve 5 8 being struck from *b* as center and with a radius equal to *b* 8 or $1\frac{3}{4}$ inches. Then using the same radius with *a* as center describe the quarter circle 5 2. Make 2 1 equal to $\frac{5}{8}$ inch, and 8 9 one inch. From the corners F and G in plan draw the miter lines F C, C G. Divide the profile of the cap into equal spaces as shown by the figures 1 to 9, from which drop vertical lines, intersecting the miter line F C as shown. On C D extended as C H place the stretchout of the profile of the cap as shown by similar numbers. At right angles to D H draw lines as shown, and intersect them by lines drawn parallel to D H from the intersections on C F. Trace a line through points thus obtained as shown by J I and trace this outline on the opposite side of the

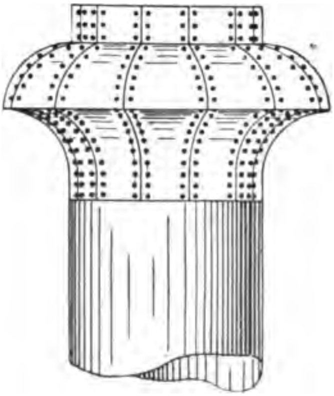


Fig. 126.

ine D H as shown by J^1 I^1. Then will J I I^1 J^1 be the complete attern for one side.

When riveting these pieces together an angle is usually placed n the inside and the miters butt sharp, filing the corners to make neat fit. This being the case the holes are punched in the pattern before bending as shown by X X X etc. Assuming that the

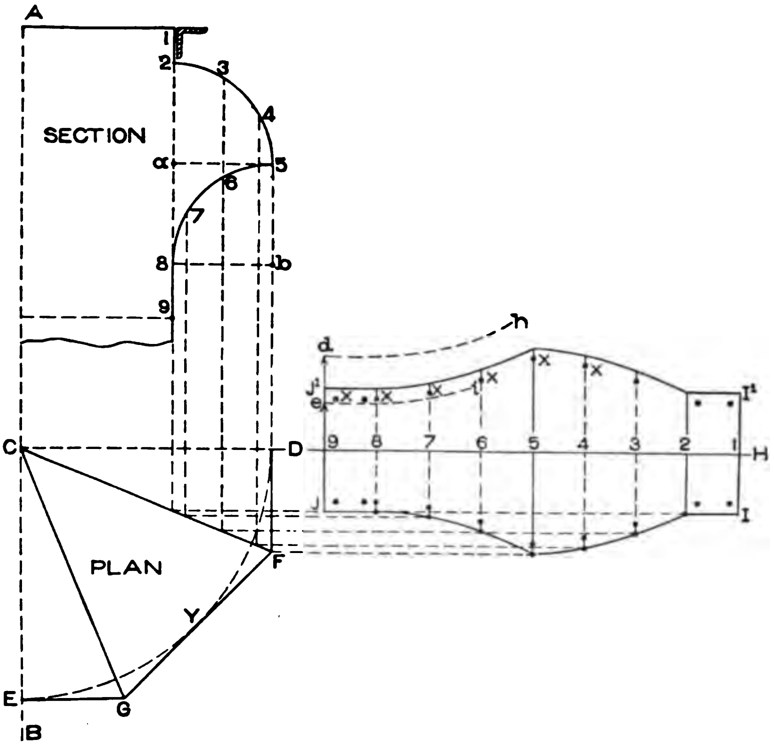


Fig. 127.

tack on which the cap is to fit is 48 inches in diameter, obtain he circumference as previously explained and divide by 8 (beause the plan is composed of 8 pieces) placing one-half of the disance on either side of the center line D H in pattern. Assuming hat $\frac{1}{16}$ of the circumference is equal to 9 *e*, trace from *e* the enire miter cut, as partly shown by *e t* to the line I^1 I. If the $\frac{1}{16}$ ircumference were equal to 9 *d*, the cut would then be traced as hown in part by *d h* until it met the line I I^1. This, of course, would be done on the half pattern 9 J I I before tracing it oppos the center line D H. Should the plan be divided into 32 pa divide the circumference of the stack by 32 and place $\frac{1}{64}$ of the c cumference on 9 J in pattern, measuring from the center line D and after obtaining the proper cut, trace opposite the line D H.

In constructing a stack where each joint tapers and fits ins of the other, as shown in Fig. 128, a short rule is employed obtaining the taper joints without having recourse to the cen In the illustration *a b* represents the first joint, the second *C* s

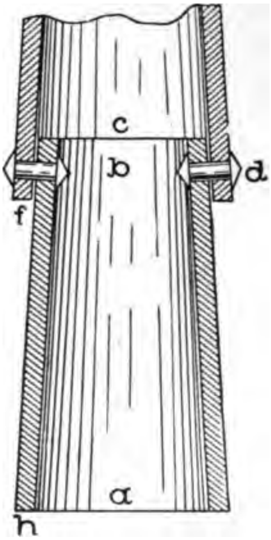


Fig. 128.

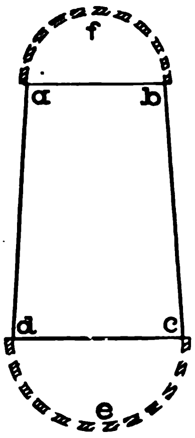


Fig. 129.

ping over it with a lap equal to *f*, the joint being riveted toge at *e* and *d*. When drawing the first taper joint *a b*, care mus taken to have the diameter at *f* on the outside, equal to the in diameter at the bottom at *h*. This allows the second joint to over a certain distance so that when the holes are punched in sheets before rolling, the holes will fit over one another after pipe is rolled.

In Fig 129 *a b c d* is a taper joint drawn on the line o inside diameter, as explained in Fig. 128 *f*, and *e* in Fig 129 resents respectively the half sections on *a b* and *d c*. By the s rule the radial lines of the cone are produced without ha recourse to the apex, which, if obtained in the full-size drawings, would be so far away as to render its use impracticable. A method similar to the following is used for obtaining the arcs for the pattern in all cases where the taper is so slight as to render the use of a common apex impracticable.

Let *a b c d*, Fig. 130, be a reproduction of *a b c d* in Fig. 129. On either side of *a d* and *b c*, in Fig. 130, place duplicates of *a b c d* as shown by *b′ c′* and *a′ d′*. This can be done most accurately by using the diagonals *d b* and *c a* as radii, and with *d* and *c* as centers describe the arcs *b b′* and *a a′* respectively, and intersect them by arcs struck from *a* and *b* as centers, with radii equal respectively to *a b* and *b a* as shown. In precisely the same manner obtain the intersection *c′* and *d′* at the bottom. Now through the intersections *b′ a b a′* and *d′ c d c′* draw the curve as shown by bending the straight-edge or any straight strip of wood placed on edge and brought against the various intersections, extending the curves at the ends and top and bottom indefinitely. Since the circumference of the circle is more than three times the diameter, and as we only have three times the diameter as shown from *c′* to *d′* and *b′* to *a′*, then multiply .1416 times the bottom and top diameter *d c* and *a b* respectively, and place one-half of the amount on either side of the bottom and top curves as shown by *e*, *e′*, and *h*, *h′*. Now take one-half of seven times the thickness of the metal in use and place

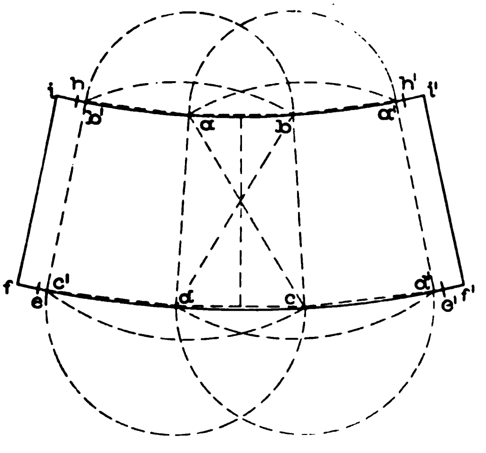


Fig. 130,

it on either side on the bottom and top curves as shown by f, f' and i, i', and draw a line from i to f and i' to f'. To this lap must be allowed for riveting. The desired pattern is shown by i i' f' f.

Fig. 131 shows a three-pieced elbow made from heavy metal, the two end pieces fitting into the center pieces, to which laps are allowed for riveting. The principles which shall be explained to cut these patterns and make the necessary allowance for any thickness of metal is applicable to any elbow.

In Fig. 132 draw as previously described the elbow A B C, below G H draw the section of the inside diameter as D which is struck from a, and divide into equal spaces as shown by the figures 1 to 5 on both sides. Through these figures draw vertical lines intersecting the miter line b c, and from these intersections parallel to c d draw lines intersecting the line d e as shown.

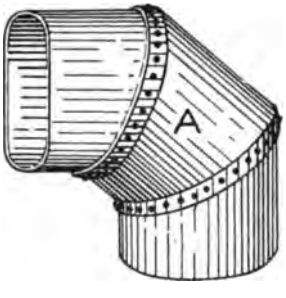


Fig. 131.

Before obtaining the stretchout for these elbows, a preliminary drawing must be constructed, in which an allowance is made for the thickness of the material that is to be used. This drawing makes practical use of a principle well known to draughtsmen from its application to the proportional division of lines and is clearly shown at (R). In allowing for the thickness of the metal in use, it is evident that we cannot allow it at one end, but must distribute it uniformly throughout the pattern. In (R) draw any horizontal line as E F, upon which place the stretchout of the inside diameter of the pipe D, as shown by similar figures on E F. From 1^{O} on E F lay off the distance 1^{O} m equal to 7 times the thickness of the metal in use as before explained. Then using E as center and E m as radius, draw the arc m 1′ intersecting the vertical line drawn from 1^{O}, and from the various intersections from 1 to 1^{O} on E F erect perpendiculars intersecting the slant line 1 1′ at 2′ 3′ 4′, etc., as shown. The slant line 1 1, with the various intersections is now the correct stretchout for the elbow made of such heavy material called for by the specifications. On G H extended, as H I, place the stretchout of the slant line 1 1′ as shown from 1 to 1′ on H I. At right angles to H I and from the various intersections, erect lines, which are intersected by lines drawn parallel to II I from similar numbered intersections on the miter line *b c*. Trace the curve L M. L M I II shows the pattern for the two end pieces of the elbow.

As the middle section A in Fig. 131 is to overlap the two end pieces, it is unnecessary to allow for any additional thickness on account of this lap when suitable flanging machines are available; but since it is desirable, in some instances, to make an allowance in the pattern for riveting, the method of allowing for this lap will be explained.

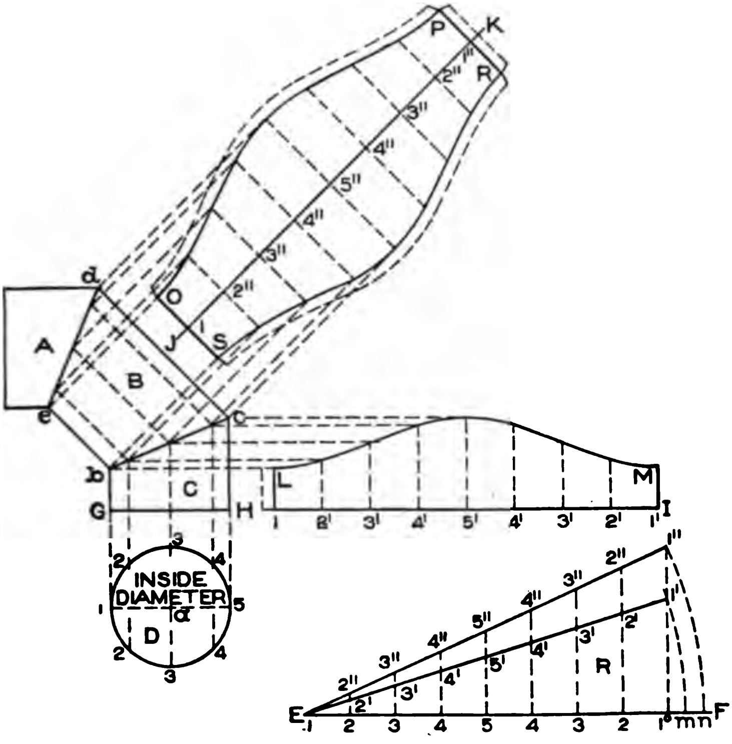


Fig. 132.

In (R), Fig. 132, lay off on the line E F the distance *m n* equal to 7 times the thickness of the metal in use, and with radius equal to E *n* draw an arc intersecting the line 1° 1′ extended at 1″. Draw the slant line from 1″ to 1 and extend all the vertical lines to intersect 1 1″ at 2″ 3″ 4″, etc. The slant line 1 1″ is the correct stretchout for the middle section B. At right angles to draw J K equal to 1 5″ 1″ in (R), as shown by similar figure J K, through which draw lines at right angles to J K, and in sect them by lines drawn at right angles to *d e* as shown. T the curved lines to produce O P R S, which is the pattern for middle section, to which flanges ar lowed as shown by dotted lines.

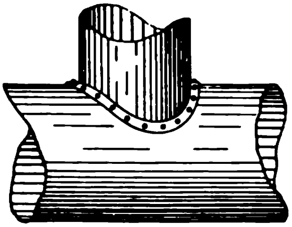


Fig. 133.

The perspective of an intersec between pipes having different di eters in boiler work is shown in 133. While the method of obtai the patterns is similar in principl parallel line developments, a sl change is required in obtaining allowance in the stretchout for the thickness of the metal in

Let A B, Fig. 134, represent the part section of a boiler st with a radius equal to $3\frac{3}{8}''$ and let 1 7 7^c 1^c be the elevation of intersecting pipe, whose inside diameter is $4\frac{7}{8}''$, as shown by

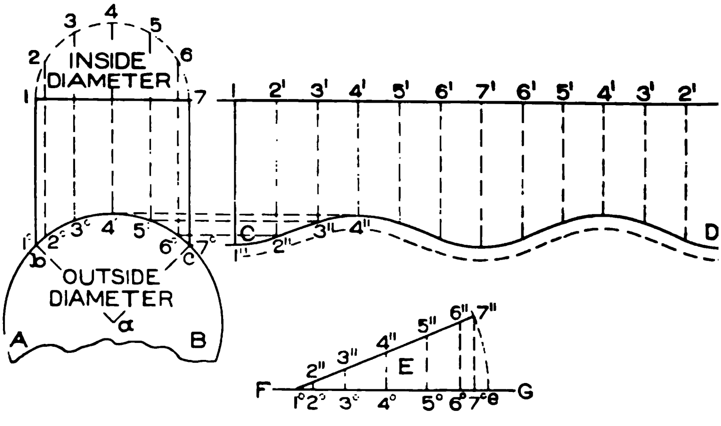


Fig. 134.

Divide the half section 1 4 7 into an equal number of space numbered, from which drop vertical lines intersecting the out line of the boiler at 1 to 7 as shown. A true stretchout must be obtained in which allowance has been made for the thick of the metal in use. Therefore, in Fig. 135, on the horiz line A B lay off the stretchout of twice the inside sectio the pipe in Fig. 134, as shown by similar figures on A B in Fig. 135, adding $1^x a$, equal to 7 times the thickness of the metal in use. For example, supposing ¼-inch steel was used; the distance $1^x a$ would then be equal to 7 × ¼, or 1¾ inches. Now draw the arc *a* 1′, using 1 as center, which is intersected by the vertical line drawn from 1^x. From 1′ draw a line to 1, and from the various points on A B erect perpendiculars intersecting 1 1′ at 2′ 3′ 4′, etc. 1 1′ shows the true stretchout to be be laid off on the line 1 7 extended in Fig. 134 as 1 1′, and from the various intersections on 1 1′ drop vertical lines and intersect them by lines drawn parallel to 1 1′ from similar intersections on the curve 1° 7° as shown. Trace a curved line as shown from C to D. 1 C D 1′ shows the pattern for the vertical pipe to which a flange must be allowed for riveting as shown by the dotted line.

It is now necessary to obtain the pattern for the shape to be cut out of the boiler sheet, to admit the mitering of the vertical pipe. In some shops the pattern is not developed, only the vertical pipe is flanged, as shown in Fig. 133, then set in its proper position on the boiler and line marked along the inside diameter of the pipe, the pipe is then removed and the opening cut into the boiler with a chisel. We give, however, the geometrical rule for obtaining the pattern, and either method can be used.

As A B in Fig. 134 represents the outside diameter of the boiler, to which 7 times the thickness of the metal used must be added to the circumference in laying out the sheet, and as the vertical pipe intersects one-quarter of the section as shown by *a b c*, take the stretchout from 1° to 7° and place it from 1° to 7° on F G in (E), to which add 7° *e*, equal to ¼ of 7 times the thickness of the plate used. Draw the arc *e* 7″, using 1° as center, intersecting it by the vertical line drawn from 7°. Erect the usual vertical lines and draw 7″ 1°, which is the desired stretchout. Now place this stretchout on the line A B in Fig. 136, erecting vertical lines as shown. Measuring in each and every instance from the line 1 7 in Fig. 134, take the various distances to points 2, 3, 4, 5, and 6 and place them in Fig. 136 on lines having similar numbers, measuring in each instance from A B on either side, thus obtaining the points 2, 3, 4, 5, and 6. Trace the curve 1° 4 7″ 4, which is the desired shape.

Fig. 137 shows a perspective of a gusset sheet A on a locomotive, the method of obtaining this pattern in heavy metal is shown in Fig. 138. First draw the end view A B C, the semicircle 4 1 4 being struck from *a* as center with a radius equal to 2 inches. Make the distance 4 to C and 4 to B both $3\frac{3}{4}$ inches and draw C B. Draw the center line A F, on which line measure up $2\frac{1}{4}$ inches and obtain *b*, which use as center with radius equal to *a* 4, draw the section of the boiler D E F G. In its proper position draw the side view H I J K L M N. H I L M N H shows the side view of the gusset sheet shown in end view by G A E D G.

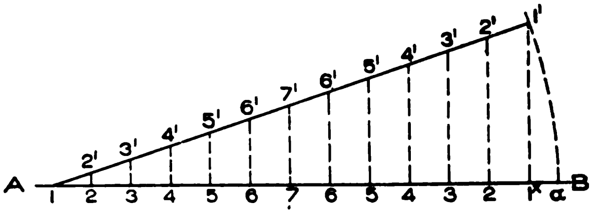


Fig. 135.

Divide the semicircle 4 1 4 in end view into equal spaces as shown, from which draw horizontal lines intersecting H N in side view from 1′ to 4′. From these intersections parallel to H I, draw lines indefinitely intersecting I L from 1″ to 4″. At right angles to N L produced draw the line at *c d*, on which a true section must be obtained at right angles to the line of the gusset sheet. Measuring from the line A D in end view, take the various distances to points 2, 3, and 4 and place them on corresponding lines measuring from the line *c d* on either side, thus obtaining

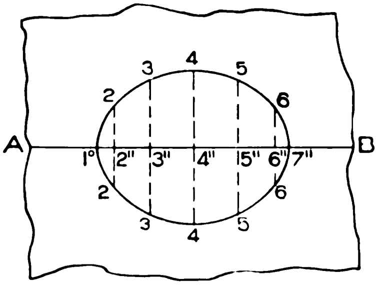


Fig. 136.

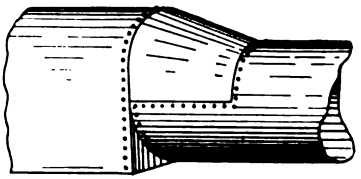


Fig. 137.

the intersections 1° to 4°, a line traced through these points will be the true section. In (Y) on any line as O P lay off the stretchout of the true section as shown from 4°, 1°, 4°. As the gusset sheet only covers a portion equal to a half circle, add the distance 4° *e* equal to ½ of 7 times the thickness of the metal in use and

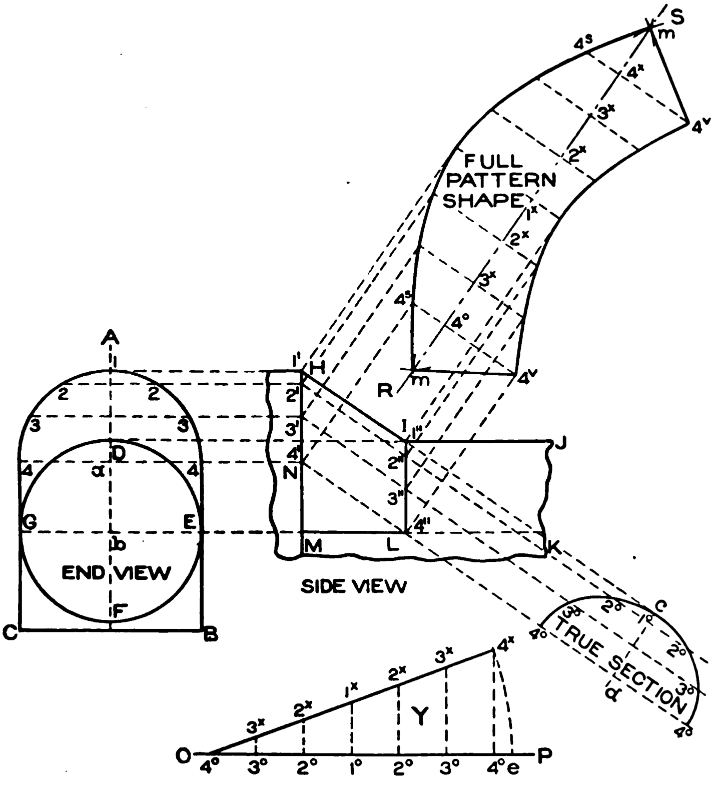


Fig. 138.

using 4° at the left, as center with 4° *e* as radius, describe the arc *e* 4^x, intersecting it at 4^x by the vertical line drawn from 4°. From O P erect vertical lines intersecting the line drawn from 4^x to 4° at 3^x, 2^x, 1^x, etc. 4° 4^x is the true stretchout, and should be placed on the line R S drawn at right angles to H I. Through the numbers on R S and at right angles draw the lines shown and intersect them by lines drawn from similarly numbered intersections on H N and I L at right angles to H I. Through points thus obtained trace a curved line 4^S, 4^S, and 4^V, 4^V. It now comes necessary to add the triangular piece shown by L M side view, to the pattern which can be done as follows: Using in side view as radius and 4^V at either end of the pattern as ters, describe the arcs *m* and *n*; intersect them by arcs struck f 4^S and 4^S as centers, and M N in side view as radius. Then lines from 4^S to *m* to 4^V in the pattern on either side. The full tern shape for the gusset sheet will then be shown by *m* 4^S 4^V 4^V, to which laps must be allowed for riveting.

Fig. 139 shows a conical piece connecting two boilers the flare of A such that the radial lines can be used in develo the pattern. In all such cases this method should be used in erence to that given in connection with Fig. 130. Thus in 139 the centers of the two boilers are on one line as shown by While the pattern is developed the same as in flaring work method of allowing for the metal used is shown in Fig. 140.

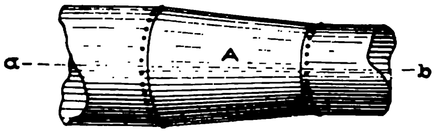


Fig. 139.

A B C D is the elev of the conical piece, the inside section being sl by 1 4 7 which is div into equal spaces. 1 7 (E) is the full stretcho the inside section A 4 elevation, and 1 *e* is equal to 7 times the thickness of the used. The line 1 1′ is then obtained in the usual manner a the various intersections 2′ 3′ 4′, etc. Now extend the lines and D C in elevation until they meet the center line *a b* Then using *a c* and *a d* draw the arcs 1′ 7′ and 1″ 7″. Fr draw a radial line to *a*, intersecting the inner arc at 1″. No the dividers equal to the spaces on 1 1′ in (E) and starting fr in the pattern step off 6 spaces and draw a line from 7′ to *a* i secting the inner arc at 7″. 1′ 7′ 1″ 7″ shows the half patte which flanges must be allowed for riveting.

Fig. 141 shows a view of a scroll sign, generally ma heavy steel, heavy copper, or heavy brass. So far as the si concerned it is simply a matter of designing, but what sh given attention here is the manner of obtaining the patter elevation of the scroll. As these scrolls are usually rolled ı of a spiral, the method of drawing the spiral will first hown. .

Establish a center point as *a'* in Fig. 142, and with the desired us describe the circle shown, which divide into a polygon of

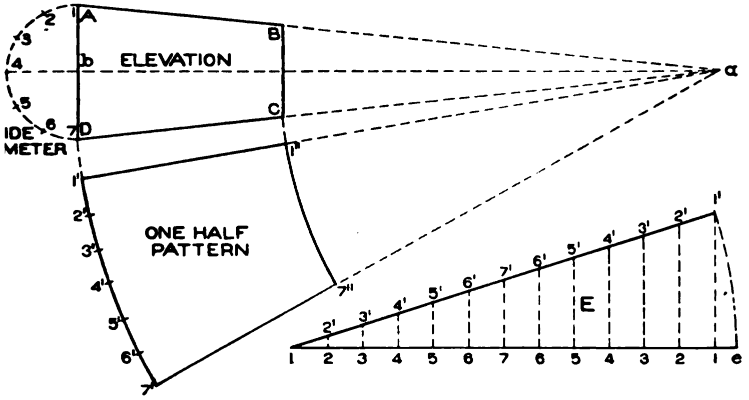


Fig. 140.

number of sides, in this case being 6 sides or a hexagon. more sides the polygon has, the nearer to a true spiral will figure be. Therefore number the corners of the hexagon 1 to

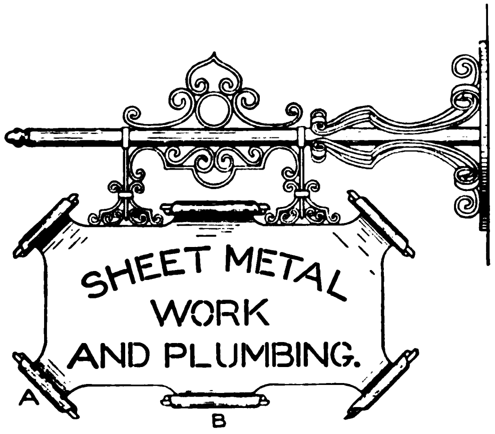


Fig. 141.

ıd draw out each side indefinitely as 1 *a*, 2 *b*, 3 *c*, 4 *d*, 5 *e*, and Now using 2 as center and 2 1 as radius, describe the arc ; then using 3 as center and 3 A as radius, describe the arc

A B, and proceed in similar manner using as radii 4 B, 5 C, 6 D, and 1 E, until the part of the spiral shown has been drawn. Then using the same centers as before continue until the desired spiral is obtained, the following curves running parallel to those first drawn. The size of the polygon *a′*, determines the size of the spiral.

In Fig. 143 let A B C D represent the elevation of one corner of the flag sign shown in Fig. 141. In its proper position in Fig. 143 draw a section of the scroll through its center line in elevation as shown by *a* 17 to 1, which divide into equal spaces as shown from 1 to 17. Supposing the scroll is to be made of $\frac{1}{8}$ inch thick metal, and as the spiral makes two revolutions then multiply $\frac{1}{8}$ by 14, which would equal $1\frac{3}{4}$ inches. Then on E F in Fig 144 place the stretchout of the spiral in Fig. 143, as shown by similar numbers, to which add 17 E equal to 14 times the thickness of metal in use, and draw the arc E 17′ in the usual manner and obtain the true stretchout with the various intersections as shown. Through the elevation of the corner scroll in Fig. 143 draw the center line E F, upon which place the stretchout of 17′ E, Fig. 144, as shown by similar numbers on E F in Fig. 143. At right angles to E F, through 1′ and 17′, draw 17′ 17′ equal to A B and 1′ 1′ equal to the desired width of the scroll at that point. Then at pleasure draw the curve 1′ 17′ on either side, using the straight-

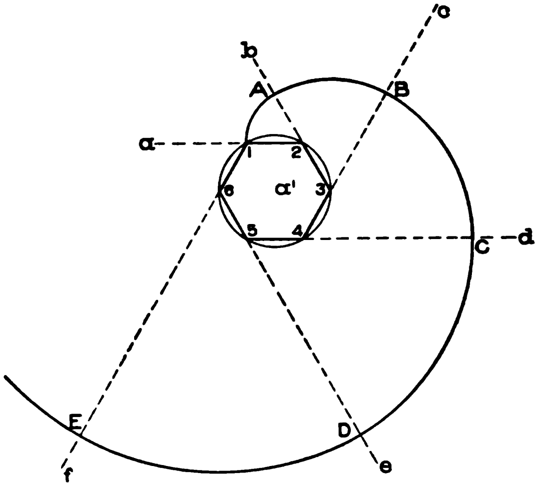


Fig. 142.

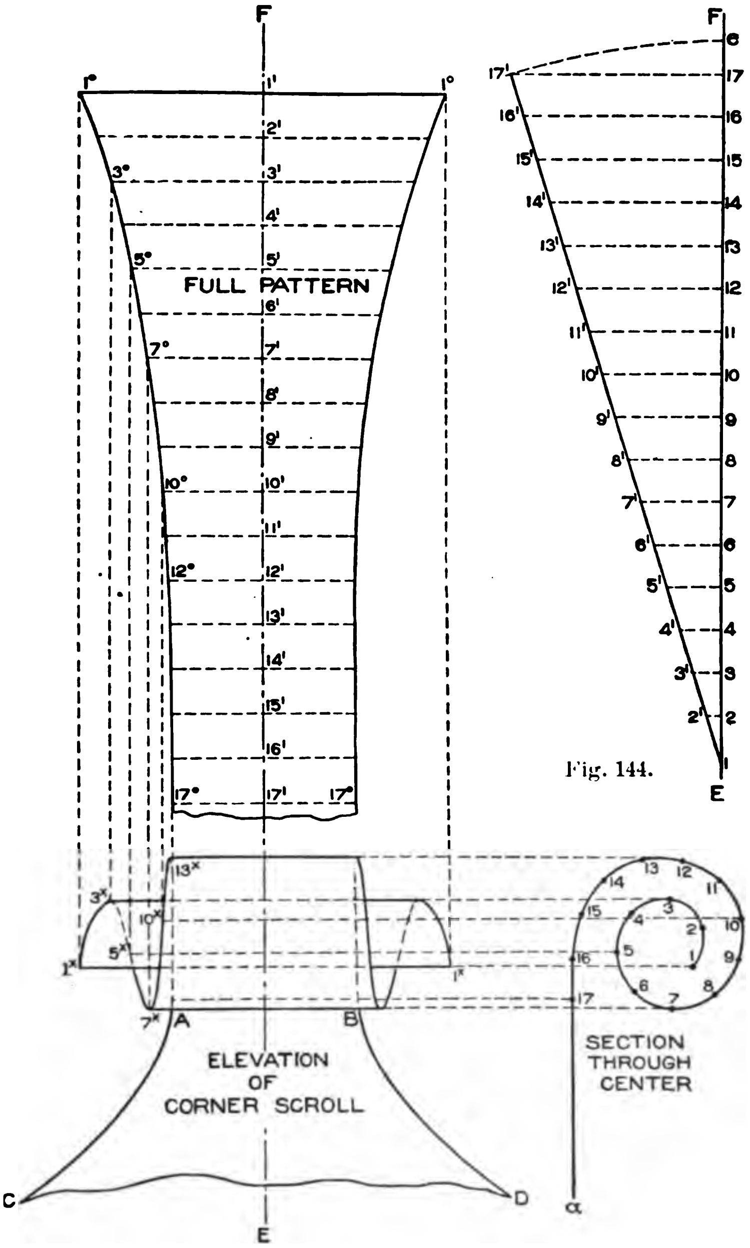


Fig. 144.

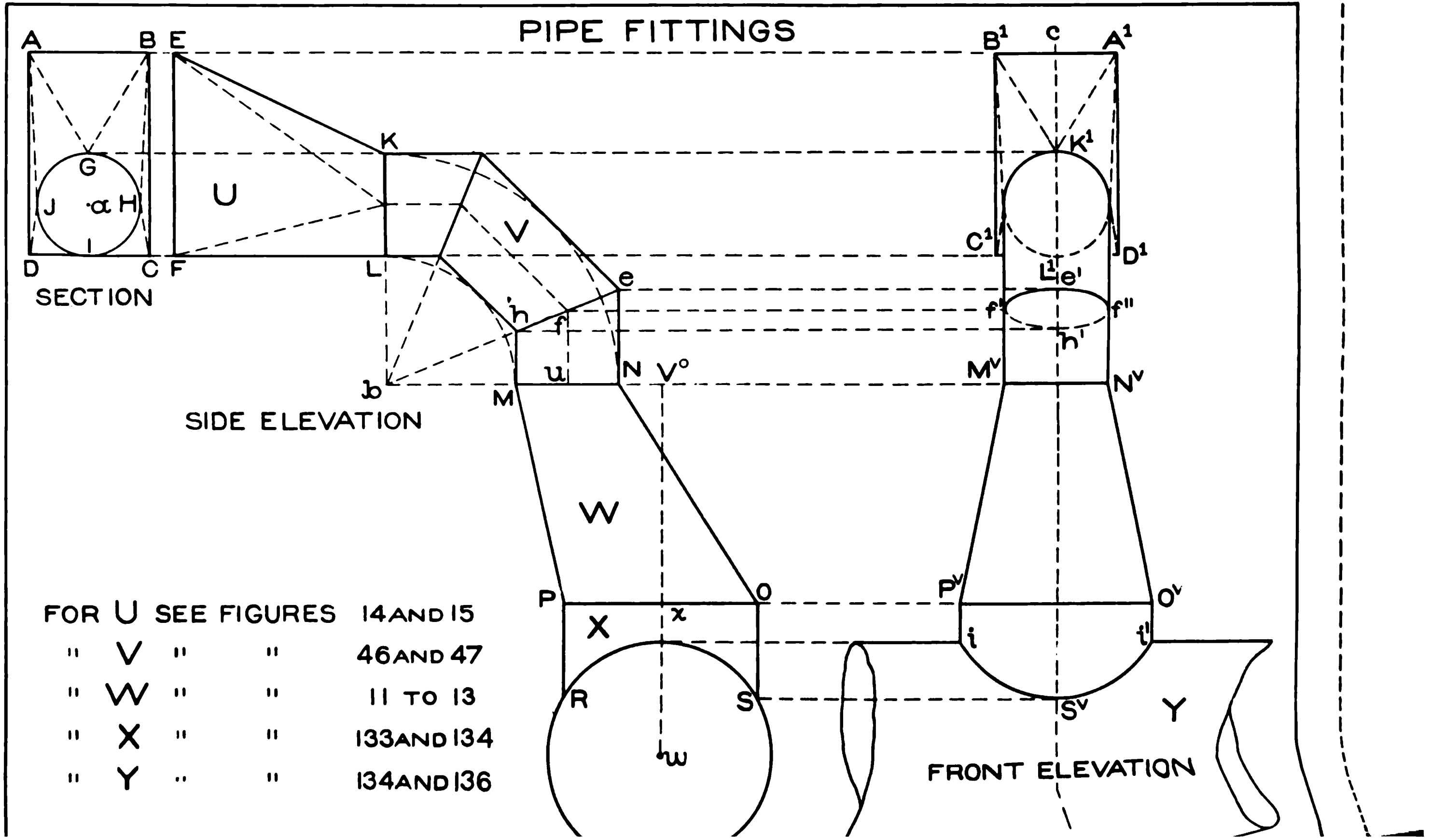
Fig. 143.

edge and bending it as required. Then will 1' 1'' 17'' 17' be the pattern for the scroll using heavy metal.

If it is desired to know how this scroll will look when rolled up, then at right angles to E F and through the intersections 1' to 17' draw lines intersecting the curves of the pattern 1'-17' on both sides. From these intersections, shown on one side only, drop lines intersecting similar numbered lines, drawn from the intersections in the profile of the scroll in section parallel to A B. To avoid a confusion of lines the points 1^x, 3^x, 5^x, 7^x, 10^x, 12^x, and 17^x have only been intersected. A line traced through points thus obtained as shown from 1^x to 17^x in elevation gives the projections at the ends of the scroll when rolled up.

PLATE III

PIPE FITTINGS



FOR U SEE FIGURES 14 AND 15
" V " " 46 AND 47
" W " " 11 TO 13
" X " " 133 AND 134
" Y " " 134 AND 136

EXAMINATION PLATES.

PLATE III.

In this plate a set of pipe fittings is shown which should be drawn by the student carefully according to the measurements which will be given. If necessary, copy it before sending for examination and correction. This plate should be laid out the same size as previous plates and the border lines drawn as before. There are five fittings shown which will require six patterns. Reproduced plates of the patterns are not sent to the student; he should work out the problems for himself according to directions given. First draw in Plate III the rectangular section A B C D, making it $1\frac{3}{8} \times 2\frac{3}{8}$ inches, with the line A B $\frac{1}{2}$-inch below the margin line, and A B $\frac{1}{4}$-inch to the right of the margin line. Now with *a* in the section as center and with radius equal to $\frac{5}{8}$-inch draw the circle G H I J so that I will be tangent at D C and G I be central in the section. Then A B C D will be the true section on E F, while G H I J shows the section on the line K L. Draw E F one-quarter inch from the line B C, and at right angles to E F, draw F L equal to $2\frac{1}{2}$ inches and from L erect the line L K $1\frac{1}{4}$ inches or equal to the height of the circle I G in section. Draw the line K E. E F L K represents the side elevation of a transition piece whose base is rectangular and whose top is round, as shown in the section. The dotted lines in section and elevations show how the figure is divided into sections of scalene cones, necessary when developing the patterns. Now extend the line K L as K *b* and with radius equal to $1\frac{1}{2}$ inches draw the quadrant L M from *b* as center. Then using *b* again as center with *b* K as radius draw the outer arc K N, intersecting the horizontal line drawn from *b*. Draw the 3-piece elbow, whose section is shown by G H I J, as explained in connection with Fig. 42, Part I. Draw the center dotted line through the elbow and from *u* on the horizonal line *b* N extended lay off a distance equal to one inch as V^{o}. From V^{o} measure down on a vertical line a. distance equal to $4\frac{3}{8}$ inches, to the point *w*. Using *w* as center with a radius equal to $1\frac{1}{4}$ inches describe the circle R S T. From *w* on the vertical line measure up a distance of 1¾ inches to x and through x draw the horizontal line O P, making x O and x P each 1⅛ inches. From O and P drop vertical lines intersecting the circle at S and R. Draw M P and N O, forming the transition piece W, which connects round pipes with diameters equal to M N and P O respectively. X shows the side elevation of the collar connecting the main pipe R S T with the transition piece W.

A front elevation of the fittings should be drawn as follows: Draw the center dotted vertical line $e\,d$ 2⅜ inches to the left of the margin line, and from the various intersections in the side elevation draw the dotted lines shown. Draw a broken view of the main pipe Y, ¼ inch from the margin line, and making both sides equal distance from the center line. Draw the intersection between the collar and main pipe as shown by $i\ S^{V}\ i'$, drawing a curved line through these points. $P^{V}\ O^{V}$ and $M^{V}\ N^{V}$ represent the same diameters as P O and M N in side elevation. They are measured on either side of the center line $e\ d$ in front elevation. $e'\ f''\ h'\ f'''$ is a front elevation through $e\ f'\ h$ in side view, while $L^1\ K^1$ is a true section on K L. $A^1\ B^1\ C^1\ D^1$ is equal to A B C D in section. Draw dotted lines showing the transition from the rectangular section to round as given in the front elevation. When this has been done Plate III is completed.

We have now five fittings for which the patterns must be developed, and for which no reproduced plates are sent. The student should follow the rules given in previous problems.

PLATE IV.

The patterns for the transition piece U and the 3-pieced elbow V constitute Plate IV.

To obtain the patterns for the transition piece U, use the description given in connection with Figs. 14 and 15, but lay off the diagram of triangles similar to the directions given in connection with Figs. 78 to 81. The patterns for the 3-pieced elbow V should be developed as described in connection with Figs. 46 and 47. These two problems U and V should be carefully laid out on similar sized plate as previously used. Care should be taken not to allow any of the patterns to come within ¼ inch of the margin line and place the patterns in such positions to make a neat appearance.

PLATE V.

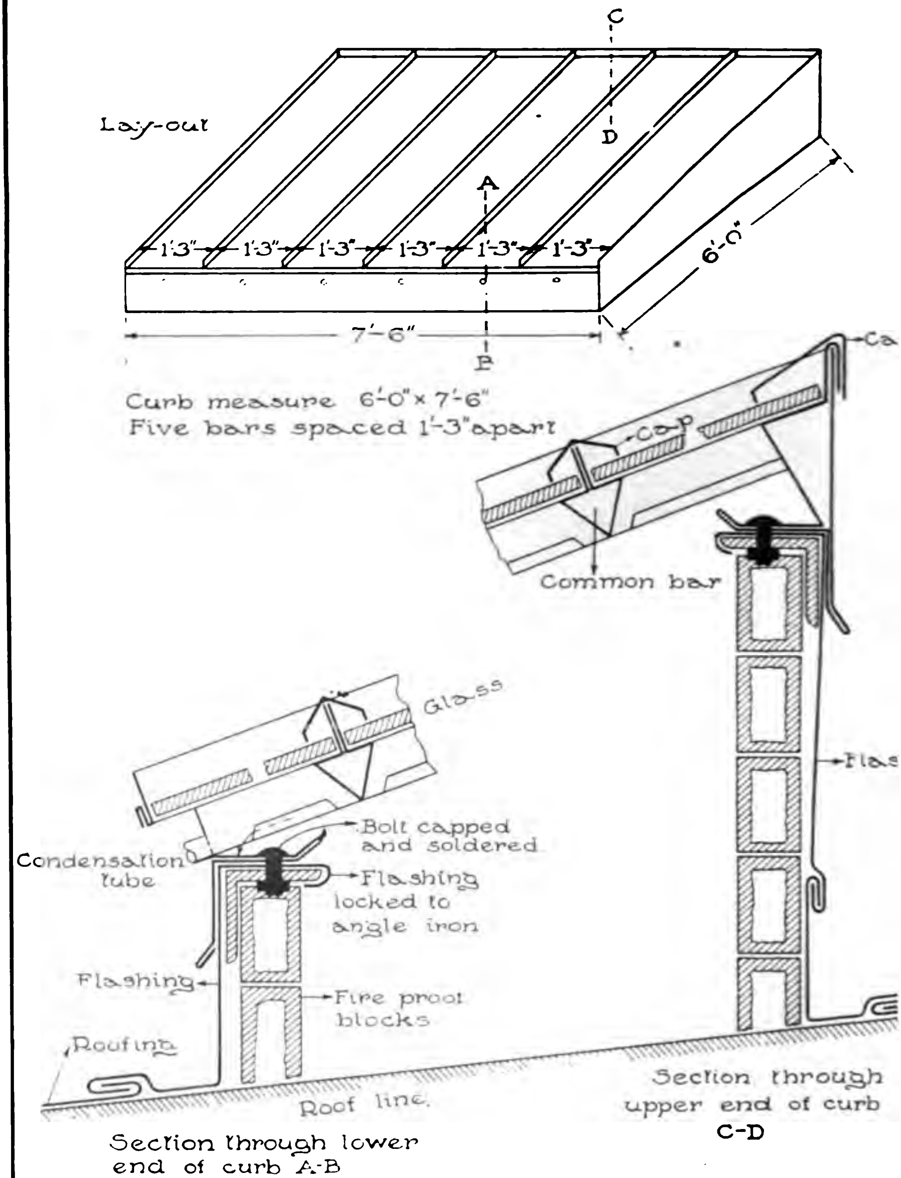
The patterns of W and X, together with the pattern for the opening in Y, constitute this plate.

To obtain the pattern for the transition piece W, use the rule described in connection with Figs. 11 to 13, and for the pattern X use rules described in connection with Figs. 133 and 134. In this case we make no allowance for the thickness of the metal as shown in those figures, but assume that we are using ordinary gauge metal. For the pattern for the opening in the main pipe Y use rules given in connection with Figs. 134.and 136, and also omit allowing for heavy material.

EXAMINATION PLATES.

Plates III to V, inclusive, constitute the Examination for this Instruction Paper. As above mentioned, Plates IV and V are drawn by the student himself, and therefore no reproduced plates are sent. The date, student's name and address, and the plate number should be lettered on each plate in inclined Gothic capitals.

CONSTRUCTION DRAWING SHOWING LAY OUT OF FLAT SKYLIGHT AND METHOD OF FASTENING FLASHING ON ANGLE IRON CONSTRUCTION.



Curb measure 6'-0" × 7'-6"
Five bars spaced 1'-3" apart

Section through lower end of curb A-B

Section through upper end of curb C-D

PRACTICAL PROBLEMS IN MENSURATION FOR SHEET METAL WORKERS.

A square tank, Fig. 1, is required whose capacity should be 200 gallons, the sides *b a* and *a c* each to be 30 inches; how high must *c d* be, so that the tank will hold the desired quantity ?

Suppose the height *c d* is to be $51\frac{1}{3}$ inches, and the tank is to have similar capacity, and one side *c a* is to be 20 inches wide, how long must the alternate side *a b* be, so that the tank will hold 200 gallons ?

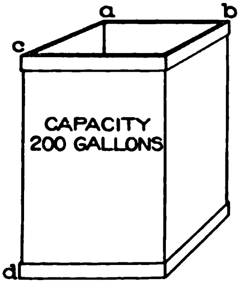


Fig. 1.

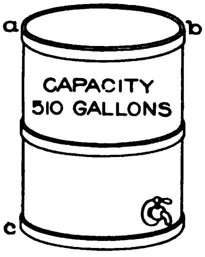


Fig. 2.

A round tank, Fig. 2, is to be constructed whose capacity should equal 510 gallons, and be 5 feet high from *c* to *a*; what must its diameter *a b* be, so as to hold the desired capacity ?

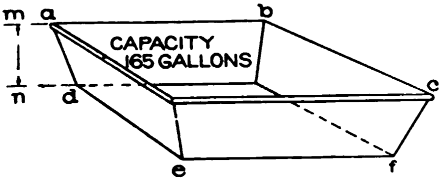


Fig. 3.

Suppose the diameter of the tank is to be 50 inches as *a b*; what must its height *a c* be, so that the tank will hold 510 gallons ?

A large drip pan, Fig. 3, is to be constructed whose capacity should be 165 gallons, and whose top measurements *a b* and *b c* are 60 × 40 inches respectively, and bottom measurements *d e* and *e f* 34 × 54 inches respectively; what must its height *m n* be, so as to hold the desired volume?

A round tapering measure, Fig. 4, is to be constructed whose volume will equal 42 quarts; its bottom diameter *a b* is to be 14 inches, its top diameter *c d* 18 inches; what must its height *e f* be to hold the desired quantity?

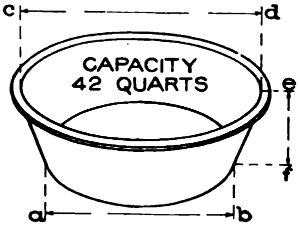


Fig. 4.

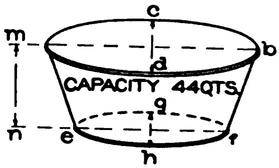


Fig. 5.

An elliptical tapering tank, Fig. 5, is to be constructed whose major axis *m b* is 24 inches, and minor axis *c d* 14 inches at the top, while at the bottom the major axis *e f* is 20 inches, and minor axis *g h* 10 inches; the capacity of the tank should equal 44 quarts; what must the height *m n* be, so that the tank will hold the desired amount?

A tank, Fig. 6, is to be constructed with semicircular ends whose capacity should equal 30 gallons; the length *a b* to be 20 inches, and the diameters of *c* and *d* to be each 10 inches; what must the height *e f* be, so that the tank will hold the desired quantity?

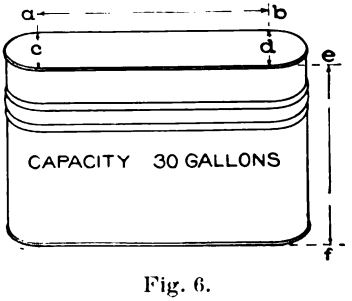


Fig. 6.

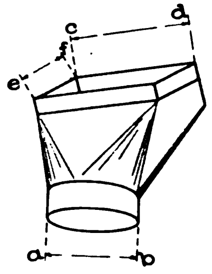


Fig. 7.

Suppose the height *e f* is to be 24 inches, the diameters *c* and *d* each 11 inches; what must the length of *a b* be, so that the tank will hold 30 gallons?

In Fig. 7 is shown a fitting used in ventilation piping; the diameter *a b* is $11\frac{1}{4}$ inches and it is desired that the oblong pipe on the opposite end shall have an area similar to the round pipe *a b*; if *e f* must be 5 inches, what must *c d* be so that both areas are alike?

Suppose the pipe is to be square in place of oblong, what must the length of each side be, so that both ends have similar area?

In Fig. 8, *a b* is 40 inches in diameter; and each one of the branches *c*, *d*, and *e* are to have equal diameters, what must the diameter of the branches be, so that the combined area of *c*, *d*, and *e* will equal the area of *a b*?

If *c* is 10 inches in diameter, *d* 12 inches, and *e* 8 inches, what must be the diameter of *a b*, to have the combined area of the branches?

Fig. 9 shows a transition piece from a round pipe *a* to an elliptical pipe *b*, both sections to have similar area; if the round pipe is 24 inches in diameter, and the major axis of the elliptical pipe must be 32 inches, what must the minor axis of *b* be so that the area at *b* will equal the area of *a*?

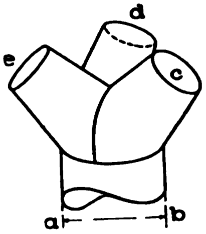


Fig. 8.

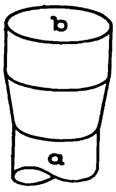


Fig. 9.

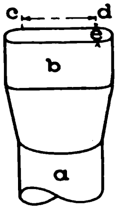


Fig. 10.

If the minor axis of *b* is to be 16 inches and the major axis 35 inches, what must the diameter of *a* be, so that both sections will have similar area?

In Fig. 10, *a* is 20 inches in diameter and forms a transition to an oblong pipe with semicircular end; the semicircular ends are to be 10 inches in diameter; what must the length of *c d* be, so that the area of *b* will be equal to the area of *a*?

If the pipe *b* measured 40 × 11 inches, having semicircular ends, what must the diameter of *a* be, so that both sections are equal in area?

If *a* is 20 inches in diameter and the upper section was to be rectangular in shape, 8 inches wide, what would the length of the upper section be?

Suppose the upper section *b* was desired to be square, what must the length of each side be, to have an area similar to *a*?

In Fig. 11 is shown the illustration of an ordinary steel square, and the method is given of obtaining accurate diameters of pipes, round or square, without any computation whatever, the rule being based on the geometrical principle that the square of the hypothenuse of a right angle triangle is equal to the sum of the squares of its base and altitude. To illustrate the rule, Fig. 12 has been prepared. Let A represent a round or square pipe, 20 inches across, and B a round or square pipe 12 inches across; it is desired to take a branch from the main so that the two branches B and C will equal the area of the main A. What must the size of C be?

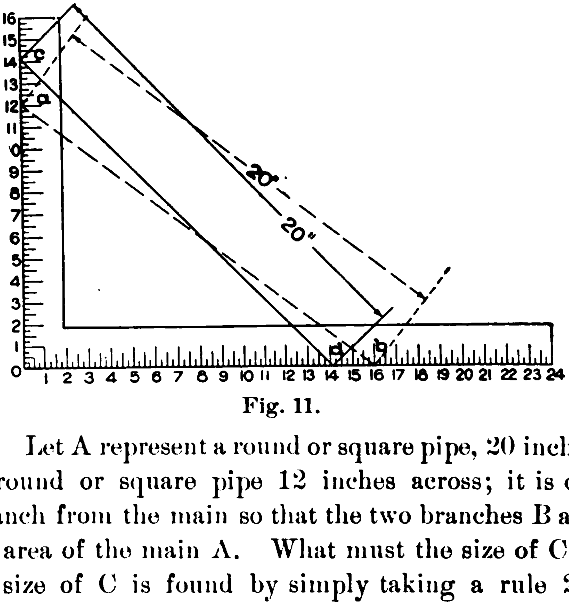


Fig. 11.

The size of C is found by simply taking a rule 20 inches long and placing one end on the arm of the square in Fig. 11, on the number 12, when the opposite end of the rule will touch the number 16. Then 16 is the required size of the branch C in Fig. 12. We can prove this by computation which, however, is not necessary in practice. The area of a 20-inch round pipe equals 314.16 in.; area of 12-in. pipe = 113.098 in.; area of 16-in. pipe = 201.062 in.; and 113.098 in. + 201.062 in. = 314.160 in. The area of a 20-in. square pipe = 400 in.; area of 12-in. square pipe = 144 in.; area of 16-in. square pipe = 256 in.; and 256 in. + 144 in. = 400 in.

Suppose any two branches are given as B and C in Fig. 12, what must the size of A be so that its area will have the combined area of the two branches?

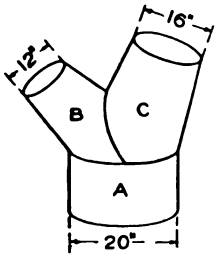
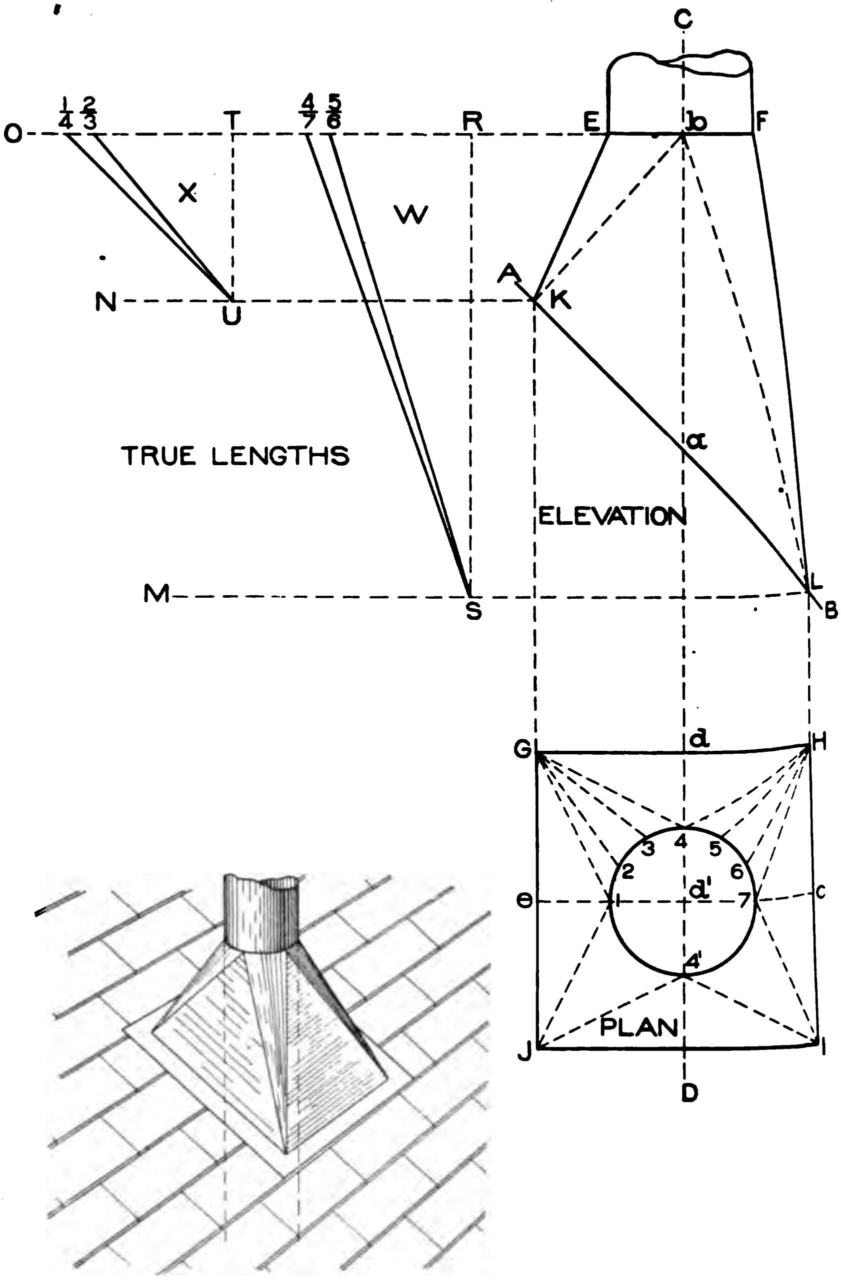


Fig. 12.

Simply set the rule on the numbers 12 and 16 on the two arms of the square respectively, and the length from *a* to *b* in Fig. 11 will measure 20 inches.

If A, Fig. 12, were given, and two branches were required, so that B and C were both of equal size, then simply set the rule 20 inches long, on both arms of the square so that the distance from O to *c* and O to *d* would be equal, as shown in Fig. 11, which would be found to measure $14\frac{1}{7}$ in. plus a least trifle. This rule can be used to advantage for any size round or square pipe in blower, blast, heat, and ventilating piping, saving time and trouble in computation. Where no square is at hand, one can be drawn on paper and used for work of this kind.



PATTERN OF TAPERING FLANGE FOR CYLINDER, DEVELOPED BY TRIANGULATION.

TINSMITHING.

An important part of the technical education of those connected with tinsmiths' work is a knowledge of laying out patterns. When making the various forms of tinware, or, as they are commonly called, housefurnishing goods, the greatest care must be taken in developing the patterns, for if a mistake of but one point is made, the pattern will be useless. There are general geometrical principles which are applied to this work which, when thoroughly understood, make that part plain and simple, which would otherwise appear intricate. These principles enable the student to lay out different patterns for various pieces of tinware where the methods of construction are similar.

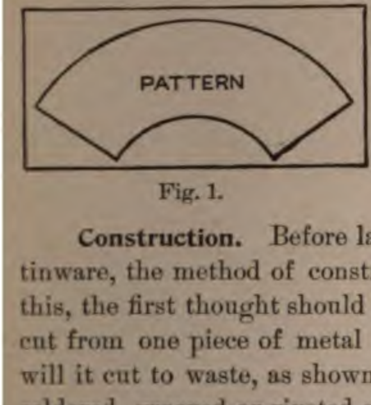


Fig. 1.

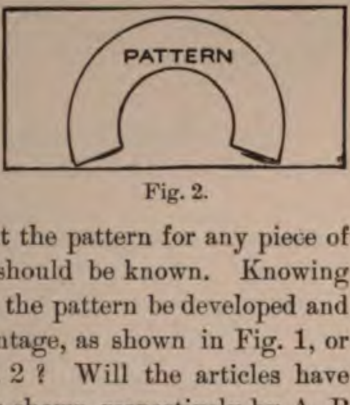


Fig. 2.

Construction. Before laying out the pattern for any piece of tinware, the method of construction should be known. Knowing this, the first thought should be: Can the pattern be developed and cut from one piece of metal to advantage, as shown in Fig. 1, or will it cut to waste, as shown in Fig. 2? Will the articles have soldered, grooved or riveted seams, as shown respectively by A, B and C, in Fig. 3? Also, will the edges be wired or have hem edges at the top, as shown respectively by A and B, in Fig. 4? Sometimes the pattern can be laid out in such a way that the article may be made up of two or more pieces, so that the patterns may be laid in one another, as shown in Fig. 5, thereby saving material. This is a plan that should always be followed if possible.

When the patterns are developed, tin plate should be obtained of such size as to have as little waste as possible.

By means of the table on pages 45–47 tin plate may be ordered which will cut to advantage, for there is nothing worse in a tinshop than to see a lot of waste plate under the benches, whereas a little foresight in ordering stock would have saved material.

Capacity of Vessels. Sometimes the tinsmith is required to make a piece of tinware which will hold a given quantity of liquid. The methods of finding the dimensions are given in Arithmetic and Mensuration, which subjects should be reviewed before beginning this work.

Shop Tools. The most important hand tools required by the tinsmith are: hammer, shears, mallet, scratch awl, dividers and soldering coppers. The other tinsmith tools and machines will be explained as we proceed.

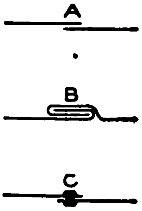


Fig. 3.

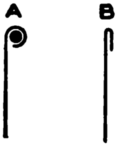


Fig. 4.

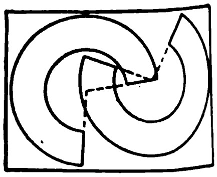


Fig. 5.

Various Methods of Obtaining Patterns. The pattern drafting for this course is divided into two classes:

1. Patterns which are developed by means of parallel lines.
2. Patterns which are developed by means of radial lines.

The principles which follow are fundamental in the art of pattern cutting and their application is universal in tinsmiths' work.

INTERSECTIONS AND DEVELOPMENTS.

The laying out of patterns in tinsmiths' work belongs to that department of descriptive geometry, known as development of surfaces, which means the laying out flat of the surfaces of the solids, the flat surfaces in this case being the tinplate. In Fig. 6 is shown one of the most simple forms to be developed by parallel lines, that of an octagonal prism. This problem explains certain fixed rules to be observed in the development of all parallel forms, which are as follows:

1. There must be a *plan, elevation* or other view of the article to be made, showing the line of joint or intersection, and

in line with which must be drawn a section or profile of the article. Thus, ABCD shows the view of the article, AL the line of joint or intersection, and E the profile or section of the article.

2. The *Profile* or section (if curved) must be divided into equal spaces (the more spaces employed the more accurate will be the pattern), from which lines are drawn parallel to the lines of the article intersecting the line of joint or intersection. Thus from the corners numbered 1 to 8 in the profile E, lines are drawn parallel to the line of the article, intersecting the line of joint AL from 1″ to 8″. In Fig. 7, where the section A is curved, this is divided into equal spaces.

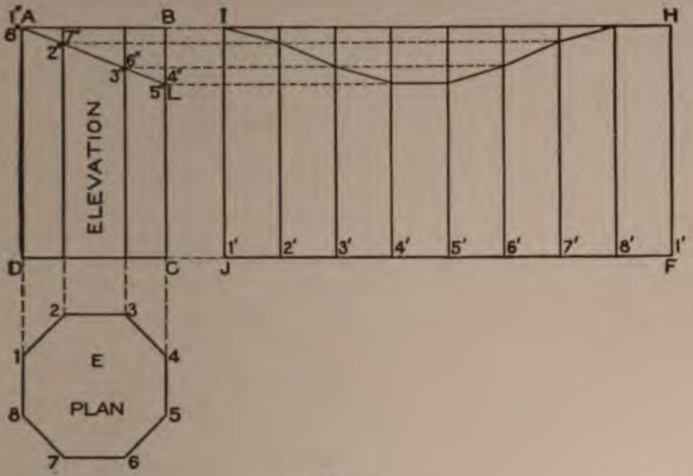


Fig. 6.

3. A *stretchout* line (showing the amount of material the article will require) is next drawn at right angles to the line of the article, upon which is placed each space contained in the section or profile. Thus JF, in Fig. 6, is the stretchout line, which contains the true amount required to enclose the profile E.

4. At right angles to the stretchout line, and from the intersections thereon, draw lines called the *measuring lines*. Thus, from the intersections 1′ to 8′ on JF lines are drawn at right angles to the stretchout line JF, which are called measuring lines.

5. From the intersections on the line of joint draw lines intersecting similarly numbered measuring lines, which will result in the pattern shape. Thus lines drawn from the intersections on

the line AL at right angles to BC intersect similarly numbered measuring lines as shown. Then JIHF will be the development for an octagonal prism intersected by the line AL in elevation.

This simple problem shows the fundamental principles in all parallel-line developments. What we have just done is similar to taking the prism and rolling it out on a flat surface. Let the student imagine the prism before him with the corners blackened and starting with corner 1 turn the prism on a sheet of white paper until the point 1 is again reached, when the result will correspond to the development shown. Bearing these simple rules in mind, the student should have no difficulty in laying out or developing the forms which will follow.

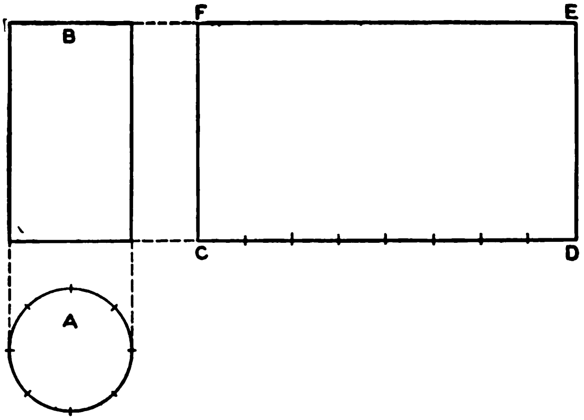


Fig. 7.

Fig. 7 shows the development of a cylinder, and also shows the principles which are applied in spacing circular sections or profiles, as explained for parallel developments. A shows the profile or section, B the elevation, and CD the stretchout line or the amount of material required to go around the circle. By drawing the measuring lines CF and DE and connecting them by the line FE, we obtain CDEF, which is the development of the cylinder.

Fig. 8 shows how to obtain the development of the surfaces of an intersected hexagonal prism, the angle of intersection being 45°. First draw the elevation ABCD and the section E in its proper position below. Number the corners in the section 1, 2 and 3, as shown, from which erect perpendicular lines intersecting the plane AB, as shown by 1°, 2° and 3°. Bisect the lines 1—1 and 3—3 in plan obtaining the points F and H respectively, and draw the line FH. This line will be used to obtain dimensions with which to construct the developed surface on the plane AB. At right angles to AB and from the intersections 1°, 2° and 3° draw lines as shown. Parallel to AB draw the line F^v H^v. Now, measuring in each instance from the line FH in E, take the distances to 1, 2 and 3, and place them on similarly numbered lines drawn from the plane AB, measuring in each instance from the line $F^v H^v$ on either side, thus obtaining the points 1′, 2′ and 3′. Connect these points by lines as shown; then J will be the true development or section on AB.

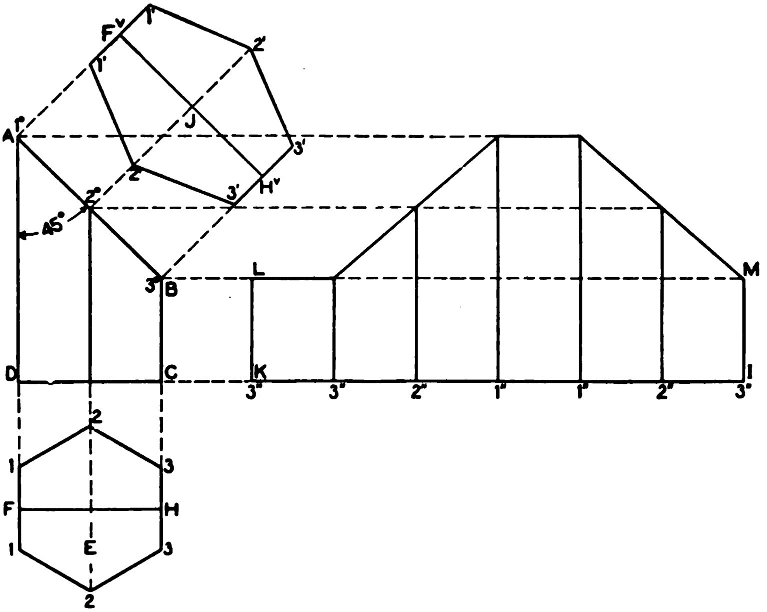


Fig. 8.

For the development of the prism, draw the stretchout line KI at right angles to AD, upon which place the stretchout of the section E, as shown by similar numbered intersections on KI. From these intersections, at right angles to KI, draw the measuring lines shown, which intersect with lines drawn from similar numbered intersections on the plane AB, at right angles to BC. Through the intersections thus obtained, draw the lines from L to

M. Then KLMI will be the pattern or development of the intersected prism.

Fig. 9 shows the development of an intersected cylinder. A is the elevation and B the profile or plan. As each half of the development will be symmetrical, divide the profile B into a number of equal parts, numbering each half from 1 to 5, as shown. From these points perpendicular lines are erected, intersecting the plane 1^v — 5^v at 1^v, 2^v, 3^v, 4^v and 5^v. A stretchout is now made of the profile B and placed on the horizontal stretchout line CD, the points being shown by 5′, 4′, 3′, 2′, 1′, 2″, 3″, 4″ and 5″. From

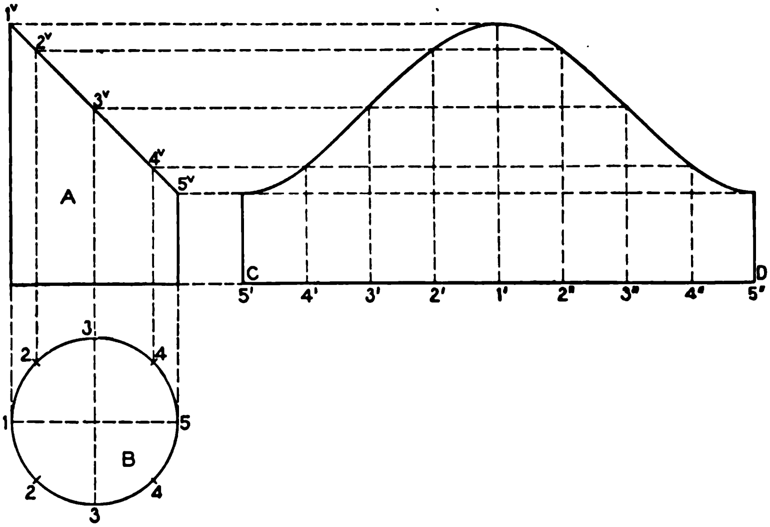


Fig. 9.

these points measuring lines are erected and intersected by similar numbered lines drawn from the plane 1^v — 5^v at right angles to the line of the cylinder. A line traced through points thus obtained will be the development of the intersected cylinder. In this case the butting edge or joint line of the cylinder is on its shortest side. If the butting edge were desired on its longest side, it would be necessary to change only the figures on the stretchout line CD, making 1′ start at 5′ and end at 5″.

Where two prisms intersect each other, as shown in Fig. 10, it is necessary to find the points of intersection before the surfaces can be developed. Thus we have two unequal quadrangular prisms intersecting diagonally at right angles to each other. We first draw the section of the horizontal prisms as shown by B in the end view, from which the side view A is projected as shown. From the corner T in the section B erect the perpendicular line TC, and above in its proper position draw the section D of the vertical prism, and number the corners 1, 2, 3 and 4. From the corners 1 and 3 drop vertical lines intersecting the profile B at 1′ and 3′, T representing the points 2′ and 4′ obtained from 2 and 4 in D. From the points 1′ and 3′ in B, draw a horizontal line through the side view, and locate the center of the vertical prism as 3″, from which erect the perpendicular line 3″ — 1. Now take a duplicate of the section D and place it as shown by F, allowing it to make a quarter turn (90°); in other words, if we view the vertical prism from the end view, the point 1 in section D faces the left, while if we stood on the right side of the end view the point 1 would point ahead in the direction of the arrow. The side view therefore represents a view standing to the right of the end view, and therefore the section F makes a quarter turn, bringing the corner 1 toward the top. From points 2 and 4 in section F drop vertical lines intersecting the line drawn from the corner 2′ — 4′ in B, thus obtaining the intersections 2″ — 4″ in the side view. Draw a line from 4″ to 3″ to 2″, which represents the intersection between the two prisms.

To develop the vertical prism, draw the horizontal stretchout line HI, and upon it place the stretchout of the profile D as shown by similar figures on HI. Draw the measuring lines from the points 1, 2, 3, 4, 1, at right angles to HI, which intersects with lines drawn at right angles to the line of the vertical prism from intersections having similar numbers on B. A line traced through the points thus obtained, as shown by HILJ will be the development of the vertical prism. The development of the horizontal prism with the opening cut into it to admit the joining of the vertical prism is shown in Fig. 11, and is drawn as follows: Draw any vertical line O^v P^v, and on this line place the stretchout of the upper half of section B in Fig. 10, as shown by similar letters and figures in Fig. 11. From these points at right angles to O^v P^v draw lines equal in length to the side view in Fig. 10. Draw a line from U to T in Fig. 11. Now, measuring from the line RS in side view in Fig. 10, take the various distances to points of in-

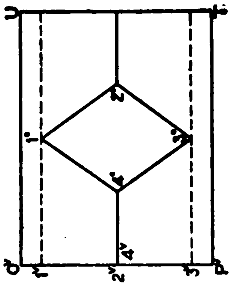
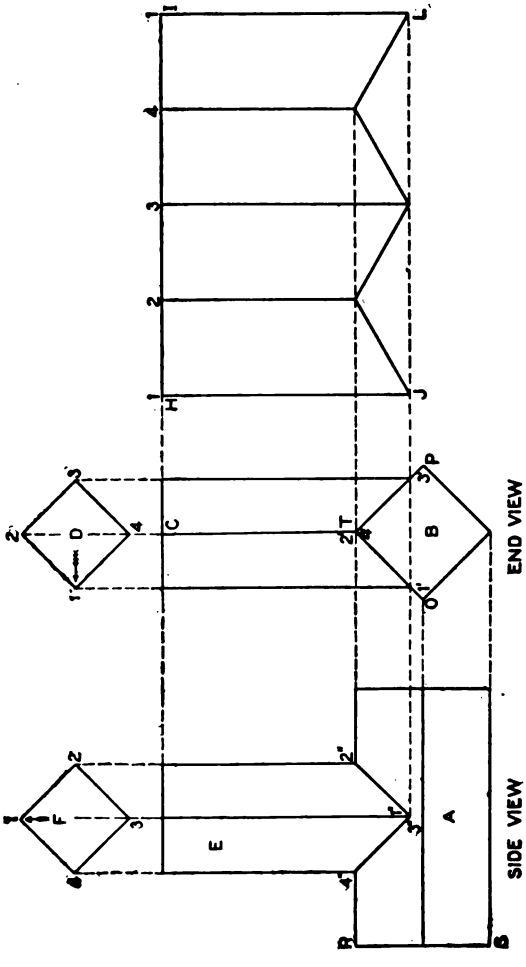

U
T
O'
P'
1'
2'
3'
4'
1V
2V
3V
4V

Fig. 11.


I
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1'
2'
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4'
E
F
A
R
S
END VIEW
SIDE VIEW

Fig. 10.

tersections 4″, 3″, 1″ and 2″, and place them in Fig. 11 on lines having similar numbers, measuring from the line $O^v P^v$, thus resulting in the intersections 1°, 2°, 3° and 4°. Connecting these points by lines as shown, then O^vUTP^v will be the half development of the top of the horizontal prism. The bottom half will he similar without the opening.

Having described the principles relating to parallel forms, the next subject will be the principles relating to tapering forms. These forms include only the solid figures that have for a base the circle, or any of the regular polygons, also figures of unequal sides which can be inscribed in a circle, the lines drawn from the corners of which terminate in an apex, directly over the center of the base. The forms with which the tinsmith has to deal are more frequently frustums of these figures, and the method used in developing these surfaces is simply to develop the surface of the entire cone or pyramid, and then by simple measurements cut off part of the figure, leaving the desired frustum. Thus in the well-known forms of the dipper, coffee pot, colander, strainer, wash bowl, bucket, funnel, measure, pan, etc., we have the frustums of cones above referred to. In speaking here of metal plate articles as portions of cones, it must be remembered that all patterns are of surfaces, and as we are dealing with tinplate, these patterns when formed are not solids, but merely shells. In works upon Solid Geometry the right cone is defined as a solid with a circular base, generated by the revolution of a right-angle triangle about its vertical side called the axis.

This is more clearly shown in Fig. 12, in which is shown a right cone, which contains the principles applicable to all frustums of pyramids and cones. ABC represents the elevation of the cone; the horizontal section on the line BC being shown by GDEF, which is spaced into a number of equal parts, as shown by the small figures 1 to 12. As the center or apex of the cone is directly over the center *a* of the circle, then the length of each of the lines drawn from the small figures 1 to 12 to the center *a* will be equal both in plan and elevation. Therefore to obtain the envelope or development, use AB or AC as radius, and with A in Fig. 13 as center, describe the arc 1 – 1′. From 1 draw a line to A and starting from the point 1, set off on the arc 1 – 1′ the stretchout or number of spaces contained in the circle DEFG in Fig. 12, as shown by similar figures in Fig. 13. From 1′ draw a line to A. Then A – 1 – 7 – 1′ will be the development of the right cone of Fig. 12.

Suppose that a frustum of the cone is desired as shown by HICB, Fig. 12; then the opening at the top will be equal to the small circle in plan, and the radius for the pattern will be equal to AI. Now using A in Fig. 13 as a center with AI as radius, describe the arc HI, intersecting the lines 1A and A1′ at H and I respectively. Then H – I – 1′ – 7 – 1 will be the development for the frustum of the cone.

When a right cone is cut by a plane passed other than parallel to its base, the method of development is somewhat different. This is explained in connection with Fig. 14, in which A is the right cone, intersected by the plane represented by the line DE. B represents the plan of the base of the cone, whose circumference is divided into equal spaces. As the intersection of both halves of the cone are symmetrical, it will be necessary to divide only half of plan B as shown by the small figures 1 to 7. From these points, erect lines parallel to the axis of the cone, intersecting the base line of the cone. From these points draw lines to apex F, intersecting the line DE as shown. From the intersections thus obtained on the line DE and at right angles to the axis, draw lines as shown, intersecting the side of the cone FE. Now using F as center and FH as a radius, describe the arc 7 - 7′. From 7 draw a line to F, and

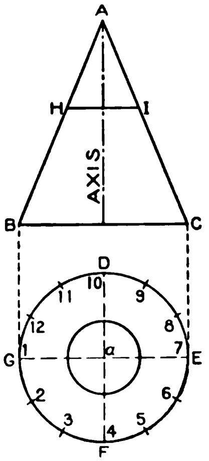


Fig. 12.

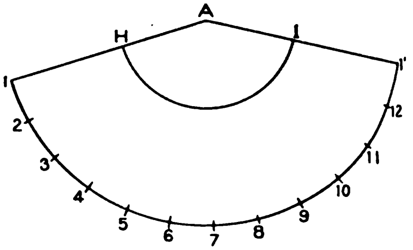


Fig. 13.

starting from the point 7 set off on the arc 7 – 7′, the stretchout of the circle B as shown by the small figures 7 – 1 – 7′. From these points draw radial lines to the center point F, and intersect them by arcs struck from the center F, with radii equal to similarly numbered intersections on the side FH, and partly shown by points $7^v - 1^v - 7^\circ$. Trace a line through the points of intersections thus obtained; then $7^\circ - 7^v - 7 - 7'$ will be the desired development.

These same principles are applicable no matter at what angle the cone is intersected. For the section on the line DE, see the explanation in Mechanical Drawing Part III.

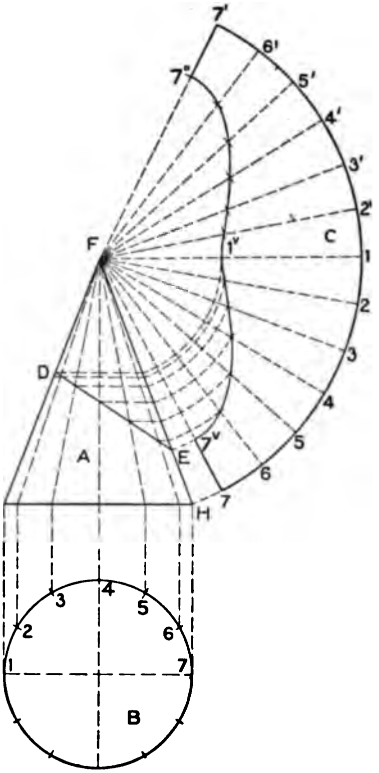


Fig. 14.

Fig. 15 shows the principles applicable to the developments of pyramids having a base of any shape. In this case, we have a square pyramid, intersected by the line DE. First draw the elevation of the pyramid as shown by ABC and in its proper position the plan view as shown by 1, 2, 3, 4. Draw the two diagonal lines 1 – 3 and 2 – 4 intersecting each other at A′. The length of the line AC represents the true length on A′*e*, but is not the correct radius with which to strike the development.

A true length must be obtained on the line A′4 as follows: At right angles to 3 – 4 from the center A′ draw the line A′E′ and using A′ as center and A′4 as radius, describe the arc 4E′ intersecting A′E′ at E′. From E′ erect the perpendicular line $E'1^v$ intersecting the base line BC extended at 1^v. From 1^v draw a straight line to A, which will be the true length on A′4 and the radius with which to strike the development. (See also Part III, Mechanical Drawing) Now with A as center and $A-1^v$ as radius, describe the arc $1^v-3^v-1^v$. Starting from 1^{v} set off the stretchout of 1 - 2 - 3 - 4 - 1 in plan, as shown by $1^{v}-2^{v}-3^{v}-4^{v}-1^{v}$ on the arc $1^{v}-1^{v}$ ($1^{v}-2^{v}$ being equal to 1 - 2, etc.), and from these points draw lines to the apex A and connect points by straight lines as shown from 1^{v} to 2^{v}, 2^{v} to 3^{v}, 3^{v} to 4^{v} and 4^{v} to 1^{v}. Then A1^{v} 3^{v} 1^{v} will be the development of the square pyramid.

To obtain the cut, in the development of the intersected plane

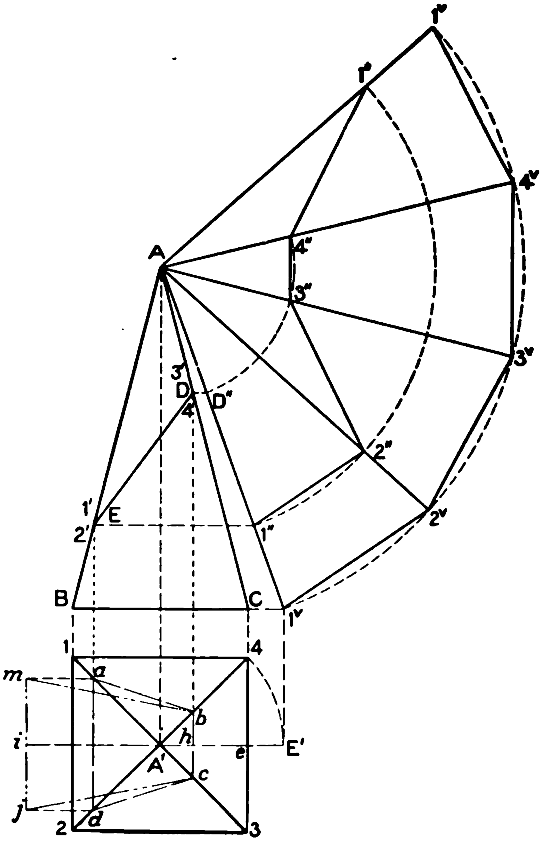


Fig. 15.

DE, which represents respectively the points $3^{1}-4^{1}$ and $1^{1}-2^{1}$, draw at right angles to the center line, the lines D - D'' and E-1'', intersecting the true length A1^{v} at D'' and 1''. Using A as center and radii equal to A - D'' and A - 1'' intersect similarly numbered radial lines in the development. Connect these points as shown from $1''$ to $2''$, $2''$ to $3''$, $3''$ to $4''$ and $4''$ to $1''$. Then $1''-1^{v}-3^{v}-1^{v}-1''-3''$ will be the development of the intersected square pyramid.

To draw DE in plan drop perpendiculars from D and E intersecting the diagonal lines in plan at *b c* and *d a*. Connect lines as shown at *a*, *b*, *c* and *d*. To obtain the true section of the plane DE, take the length of DE and place it, as shown in plan from *h* to *i*; through *i* draw the vertical line *jm* which is intersected by horizontal lines drawn from points *a* and *d*. Draw a line from *b* to *m* and *c* to *j* which will be the desired section.

These problems just described should be thoroughly studied and practiced on paper, until every step is well understood.

Practical Workshop Problems will now be considered, and the student who thoroughly understands the principles explained in the foregoing problems, will be able to develop the patterns with greater ease and in less time than is required by the student, who pays little attention to the principles, but simply proceeds to develop the patterns by blindly following directions. A thorough knowledge of the principles renders the student independent as far as pattern problems are concerned, as he can apply them to new work.

Short Rules. There are various short rules, which, while not geometrically accurate, are sufficiently so for all practical purposes and will be introduced as we proceed. In developing patterns for any given article, the problem should be gone over carefully, locating the joints or seams, so that it can be seen, we might say in our minds' eye; by doing this a shorter rule may be employed, thus saving time and expense. The student who pays attention to these smaller details will succeed as a pattern draftsman.

Allowance for Seaming and Wiring. As we are dealing with tin plate only, we assume this to have no thickness, and therefore make no allowance for the shrinkage of the metal, when bending in the machine folder or brake.

The amount of the material to be added to the pattern for wiring will vary according to the thickness of the metal. A safe and practical plan is to use a small strip of thin metal about $\frac{1}{4}$ inch wide and curl this around the wire which is to be used as shown in Fig. 16. This will give the true amount of material required, whether the wire is to be laid in by hand or by means of the wiring machine. First bend off with plyers a sharp corner as shown at *a*, place the wire in the corner and turn A snugly around the wire as shown at B. The amount of A, or the allowance to be added to the height of the pattern is thus obtained. The vertical joint in tinware is usually a lock seam as shown in Fig. 17. Three times the width of the lock *a* must be added to the pattern. In other words, the end *b* has a single edge as *d*, while the other end *c* has a double edge as shown at *a* and *e* ; the two ends of the body joining at *f*.

In allowing these edges for the pattern, some workmen prefer to add a single edge on one side of the pattern, and a double edge on the other, while others prefer to allow one-half of the amount required on either side of the pattern. Where the bottom of any piece of tinware is to be joined to the body, it is generally double seamed as is shown in Fig. 18, where the two operations are clearly shown by A and B whether the seaming is done by hand or machine, while the lock seam in Fig. 17, is done on the groover.

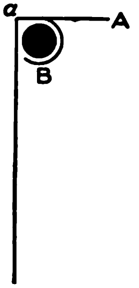


Fig. 16.

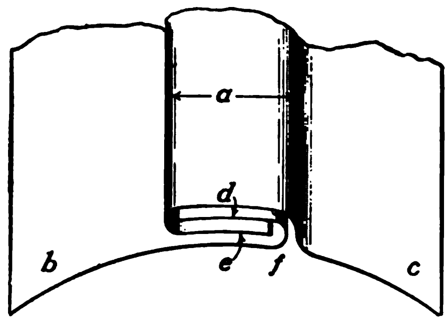


Fig. 17.

Notching the Patterns. Another important point is the notching of the edges of the patterns for seaming and wiring; special attention should be given to this. The notches should be made in such a manner that when the article is rolled up and the wire encased or the seams grooved, the ends of the wire or seam allowance will fit snugly together and make a neat appearance. When an article is made and the notches have not been cut properly, the wire, or uneven lines, will show at the ends of the seam. Fig. 19 shows how the allowance for wire or locks should be cut. A shows the pattern to which an allowance has been made for wire at B and for seaming to the bottom at C. In this case a single edge D has been allowed at one end of the pattern and a double edge of the other as shown at E. Then, using this method of allowance for seaming, notch the allowance for wire B and seam C on a line drawn through the solid lines in the pattern as shown by *aa* and *bb*. The notches of the allowance D and E should be cut at a small angle, as shown.

Transferring Patterns. After the pattern has been developed on manilla paper, which is generally used in the shop, it is placed on the tin plate and a few weights laid on top of the paper; then with a sharp scratch awl or prick punch and hammer, slight prick-punch marks are made, larger dots indicating a bend. The paper is then removed and lines scribed on the plate, using the scratch awl for marking the straight lines, and a lead pencil for the curved lines. After laps are added as required, it is ready to be cut out with the shears.

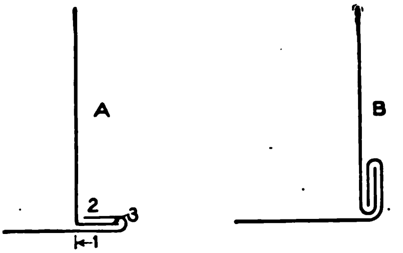


Fig. 18.

PRACTICAL PROBLEMS.

In presenting the twelve problems which follow, particular attention has been given to those problems which arise in shop practice. These problems should be practiced on cheap manilla paper, scaling them to the most convenient size, and then proving them by cutting the patterns from thin card board, and bending or forming up the models. This will prove both instructive and interesting.

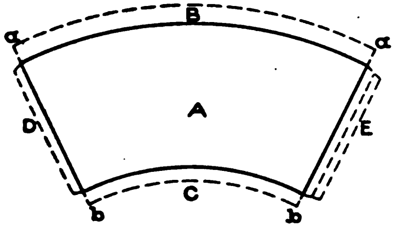


Fig. 19.

Pail. The first piece of tinware for which the pattern will be developed is that known as the flaring bucket, or pail, shown in Fig. 20. First draw the center line AB, Fig. 21, upon which place the height of the pail, as shown by CD. On either side of the center line place the half diameters CE of the top and DF of the bottom. Then EFFE will be the elevation of the pail. Extend the lines EF until they meet the center line at B, which will be the center point with which to describe the pattern. Now, with C as center and CE as radius, describe the semi-circle EAE, and divide it into equal spaces, as shown. This semi-circle will represent the half section of the top of the pail.

Fig. 20.

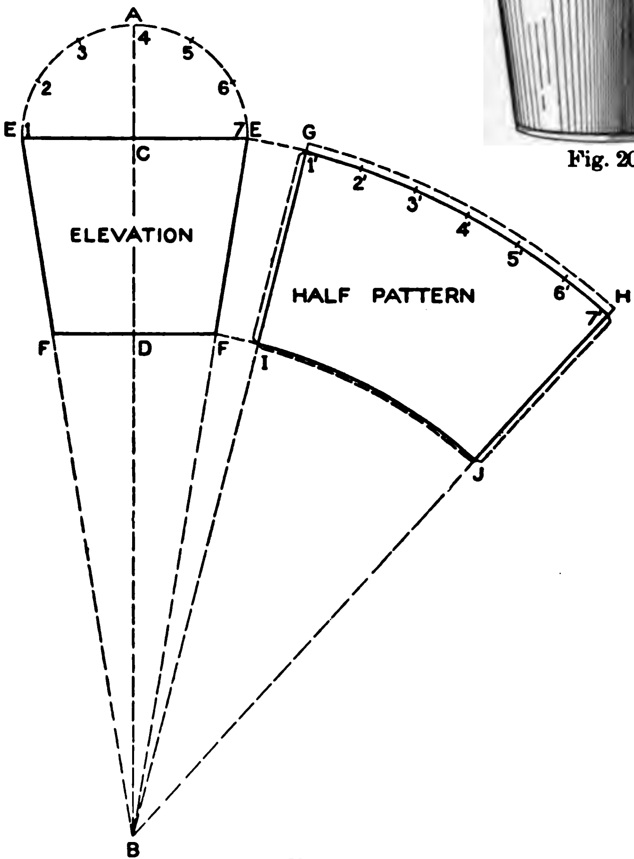


Fig. 21.

For the pattern proceed as follows: With B as center and radii equal to BF and BE, describe the arcs GH and IJ. Draw a line from G to B. Starting from the point G lay off on the arc GH, the stretchout of the semi-circle EAE, as shown by similar figures on GH. From H draw a line to B, intersecting the arc IJ at J. Then GHJI will be the half pattern for the pail, to which laps must be added for seaming and wiring as shown by the dotted lines.

Funnel and Spout. In Fig. 22 is shown a funnel and spout, which is nothing more than two frustums of cones joined together.

Fig. 23 shows how the patterns are developed. In this figure the full elevation is drawn, but in practice it is necessary to draw only one-half of the elevation, as shown on either side of the center line BC. Extend the contour lines until they intersect the center line at C and A. Now, using A^1 as a center, with radii equal to AF and AE, describe the arcs F^1F^2 and E^1E^2 respectively. On the arc E^1E^2 lay off twice the number of spaces contained in the semi-circle B, then draw radial lines from E^1 and E^2 to A^1, intersecting the inner arc at F^1F^2, which completes the outline for the

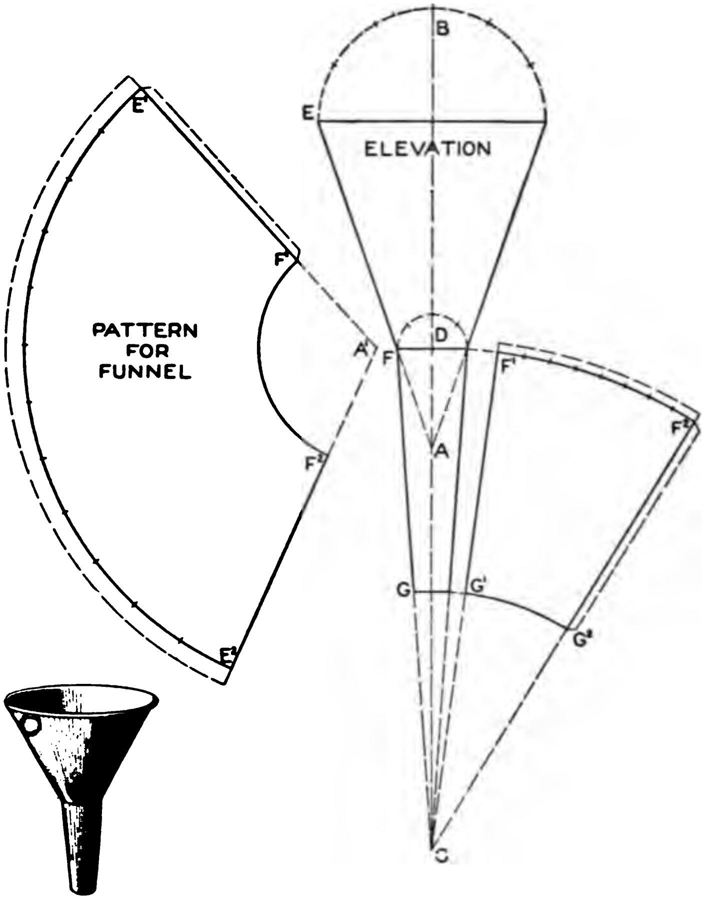


Fig. 22.

Fig. 23.

pattern. Laps must be allowed for wiring and seaming. For the pattern for the spout use C as a center, and with radii equal to CG and CF describe the arcs F^1F^2 and G^1G^2. On F^1F^2 lay off twice the amount of spaces contained in the semi-circle D, and draw radial lines from F^1 and F^2 to C. Then $F^1F^2G^1G^2$ will be the pattern for the spout. The dotted lines show the edges allowed.

Hand Scoop. In Fig. 24 is shown a perspective view of a hand scoop, in the development of which the parallel and radial line developments are employed. Thus A and B represent intersected cylinders, while C represents an intersected right cone. The method of obtaining the patterns for the hand scoop is clearly shown in Fig. 25; these principles are applicable to any form of hand scoop.

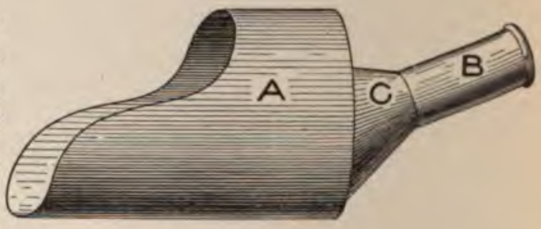


Fig. 24.

First draw the side view of the scoop as shown, in line with which place the half section; divide this into a number of equal spaces as shown by the figures 1 to 7. From these points draw horizontal lines intersecting the curve of the scoop. In line with the back of the scoop draw the vertical line 1–1′, upon which place the stretchout of twice the number of spaces contained in the half section, as shown by similar numbers on the stretchout line. From these points on the stretchout line draw horizontal lines, which intersect lines drawn from similarly numbered points on the curve of the scoop parallel to the stretchout line. Trace a line through points thus obtained, which will give the outline for the pattern for the scoop, to which edges must be allowed as shown by the dotted line. The pattern for the back of the scoop is simply a flat disc of the required diameter, to which edges for seaming are allowed.

When drawing the handle, first locate the point at which the center line of the handle is to intersect the back of the scoop, as at 2°. Through this point, at its proper or required angle, draw the center line $2^{\circ}2^{x}$. Establish the length of the handle, and with any point on the center line as center, draw the section

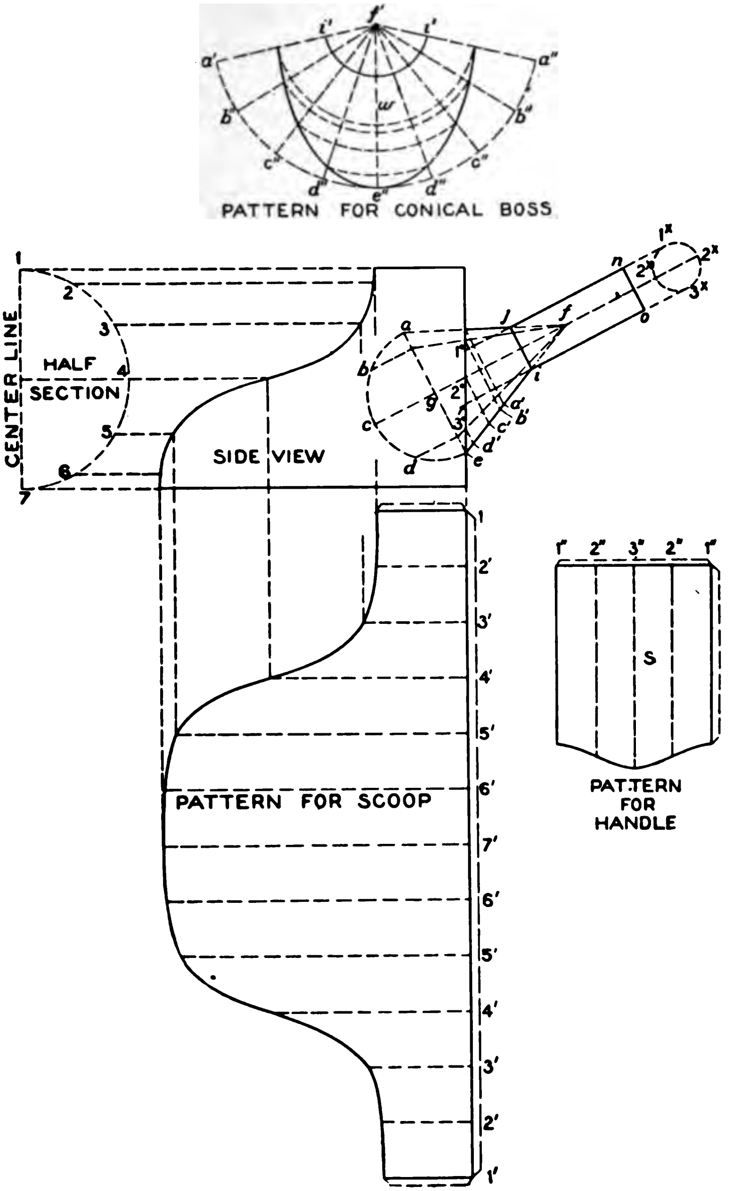

PATTERN FOR CONICAL BOSS
f'
i'
a'
a''
b''
c''
d''
e''
w
1
2
3
4
5
6
7
CENTER LINE
HALF SECTION
SIDE VIEW
a
b
c
d
e
f
g
i
j
n
o
1^x
2^x
3^x
PATTERN FOR SCOOP
1'
2'
3'
4'
5'
6'
7'
1''
2''
3''
S
PATTERN FOR HANDLE

Fig. 25.

pattern. Laps must be allowed for wiring and seaming. For the pattern for the spout use C as a center, and with radii equal to CG and CF describe the arcs F^1F^2 and G^1G^2. On F^1F^2 lay off twice the amount of spaces contained in the semi-circle D, and draw radial lines from F^1 and F^2 to C. Then $F^1F^2G^1G^2$ will be the pattern for the spout. The dotted lines show the edges allowed.

Hand Scoop. In Fig. 24 is shown a perspective view of a hand scoop, in the development of which the parallel and radial line developments are employed. Thus A and B represent intersected cylinders, while C represents an intersected right cone. The method of obtaining the patterns for the hand scoop is clearly shown in Fig. 25; these principles are applicable to any form of hand scoop.

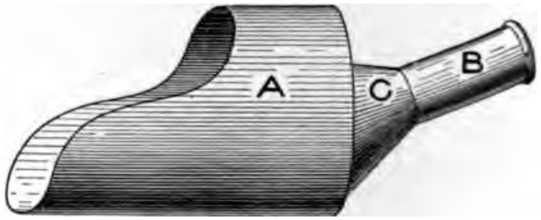


Fig. 24.

First draw the side view of the scoop as shown, in line with which place the half section; divide this into a number of equal spaces as shown by the figures 1 to 7. From these points draw horizontal lines intersecting the curve of the scoop. In line with the back of the scoop draw the vertical line $1-1'$, upon which place the stretchout of twice the number of spaces contained in the half section, as shown by similar numbers on the stretchout line. From these points on the stretchout line draw horizontal lines, which intersect lines drawn from similarly numbered points on the curve of the scoop parallel to the stretchout line. Trace a line through points thus obtained, which will give the outline for the pattern for the scoop, to which edges must be allowed as shown by the dotted line. The pattern for the back of the scoop is simply a flat disc of the required diameter, to which edges for seaming are allowed.

When drawing the handle, first locate the point at which the center line of the handle is to intersect the back of the scoop, as at $2'$. Through this point, at its proper or required angle, draw the center line $2\ 2^x$. Establish the length of the handle, and with any point on the center line as center, draw the section

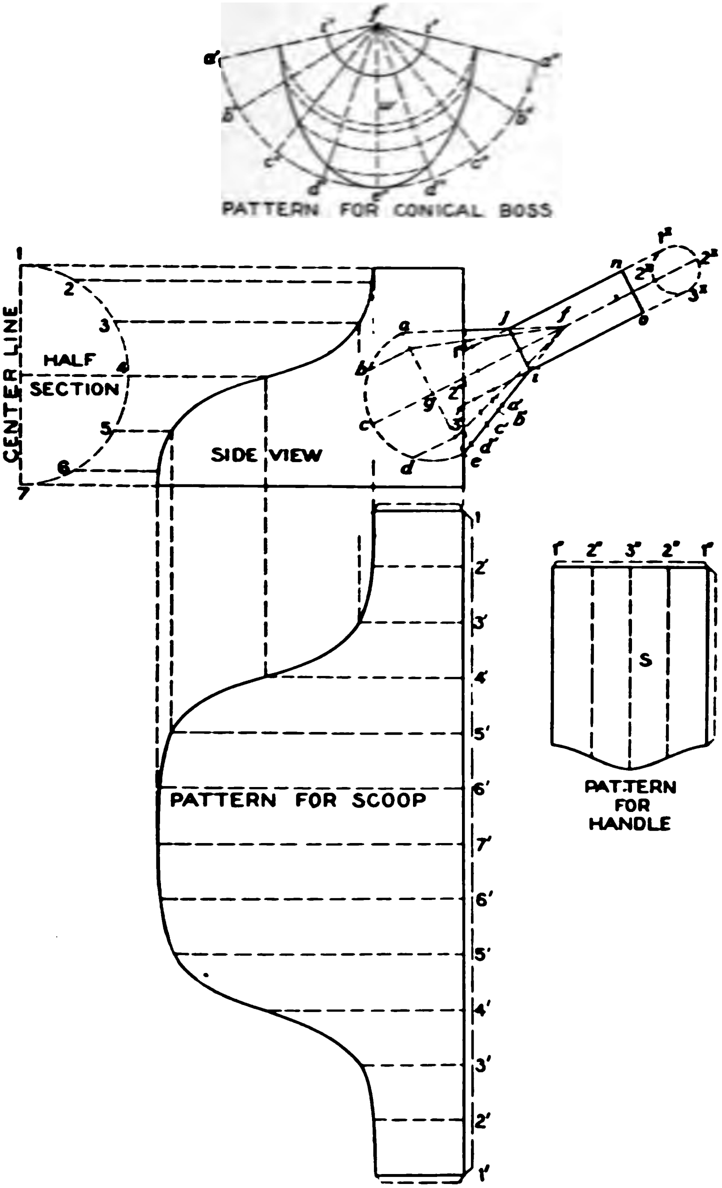

PATTERN FOR CONICAL BOSS
HALF SECTION
CENTER LINE
SIDE VIEW
PATTERN FOR SCOOP
PATTERN FOR HANDLE
S
1
2
3
4
5
6
7
1'
2'
3'
4'
5'
6'
7'
a
b
c
d
e
f
g
i
j
n
o

Fig. 25.

as shown by 1^x, 2^x 3^x, and 2^x, and divide the circumference into equal spaces, in this case four. (In practical work it would be better to use more than four). Parallel to the center line and from these four divisions draw lines as shown intersecting the back of the scoop at 1°, 2° and 3°. For the pattern draw any horizontal line in S, as $1''3''1''$, upon which place the stretchout of the section of the handle as shown by $1''$ $2''$ $3''$ $2''$ $1''$ on the stretchout line. From these points at right angles to the line of the stretchout, draw lines as shown. Take the various distances measuring from the line *no* in side view to points 1°, 2° and 3°, and place them on lines drawn from similar numbers in S, measuring from the line $1''3''1''$. A line traced through these points of intersection will be the pattern for the handle, laps being indicated by dotted lines. To close the top of the handle *no*, a small raised metal button is usually employed, which is double-seamed to the handle.

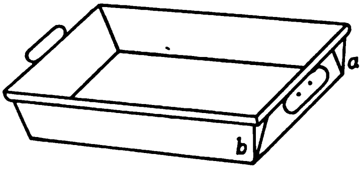


Fig. 26.

To draw the conical boss in side view, first locate the points *i* and *e*, through which draw a line intersecting the center line of the handle at *f*. At right angles to the center line, draw the line *ij* representing the top opening of the boss. In similar manner, at right angles to the center line, draw a line from *e* as shown by *ea*, intersecting the center line at *g*. Now make *ga* equal to *ge* and draw a line from *a* to the center *f*, which will intersect the back of the scoop as shown and the top of the boss at *j*. With *g* as center and *ga* as radius describe the half section of the cone, divide this into equal spaces as shown by *abcde*, from which draw lines at right angles to and intersecting the base of the cone *ae* as shown. From the intersections on the base line draw radial lines to the apex *f*, intersecting the back of the scoop as shown. From these intersections at right angles to the center line, draw lines intersecting the side of the boss at *a'b'c'd'*. For the pattern proceed as shown in diagram *w*. With radius equal to *fe* in the side view and *f'* in *w*, as a center describe the arc *a'a''*. Draw a line from *a''* to the center *f'*, and starting from *a''* set off on the arc *a'a''* twice the number of spaces contained in the semi circle *ace* in side view, as shown by similar letters in diagram *w*. From these points draw radial lines to the center *f'*. Now using *f'* in *w* as a center describe the arc *i''i''*. In similar manner, using as radii *fa'*, *fb'*, *fc'*, *fd'* and *fe* in side view, and *f'* in *w* as center, describe arcs intersecting radial lines having similar letters as shown. A line traced through points thus obtained forms the pattern for the conical boss.

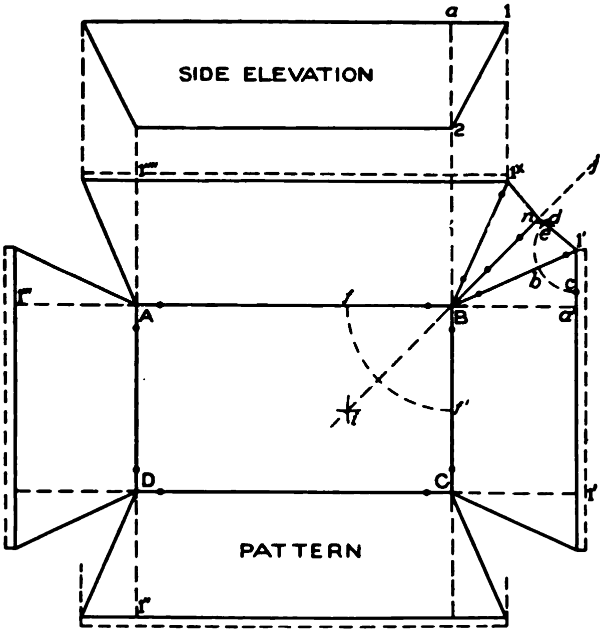


Fig. 27.

Drip Pan. Fig. 26 shows a view of a drip pan with beveled sides. The special feature of this pan is that the corners *a* and *b* are folded to give the required bevel and at the same time have the folded metal come directly under the wired edge of the pan. A pan folded in this way gives a water tight joint without any soldering. Fig. 27 shows the method of obtaining the pattern when the four sides of the pan have the same bevel. First draw the side elevation having a bevel indicated at *a*21. Now draw ABCD, a rectangle representing the bottom of the pan. Take the distance of the slant 1 - 2 in elevation and add it to each side of the rectangular bottom as shown by 1', 1'', 1''' and 1''''. Through these points draw lines parallel to the sides of the bottom as shown. Now extend the lines of the bottom AB, BC, CD and DA intersecting the lines just drawn. Take the projection of the bevel *a* to 1 in side elevation and place it on each corner of the pan, as, for example, from *a'* to 1'. Draw a line from 1' to B. By proceeding in this manner for all the corners, we will have the butt miters, if the corners were to be soldered raw edge. Where the bevels are equal on all four sides, the angle 1^xB1' is bisected as follows: With B as center and any radius draw the arc *,ff'* intersecting the sides of the bottom as shown. Then with a radius greater than one half of *,ff'*, with *,f* and *,f'* respectively as centers, draw arcs which intersect each other at *i*. Draw a line through the intersection *i* and corner B, extending it outward toward *j*.

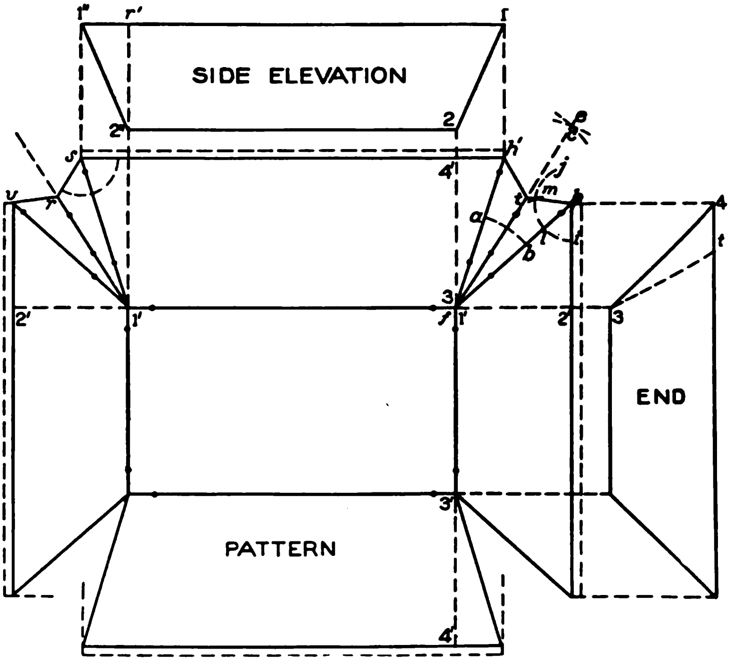


Fig. 28.

Now with 1' as center, and radius less than one-half of 1'-1^x, draw arc *d–c*, intersecting the line 1' B at *b*, and intersecting the line 1'*a'* at *c*. Then with *b* as center and *bc* as radius, intersect the arc *cd* at *e*. Draw a line from 1' to *e*, intersecting the line *ij* at *n*. From *n* draw a line to 1^x. Transfer this cut to each of the corners, which will complete the pattern desired. Dotted lines indicate the wire allowance.

Sometimes a drip pan is required whose ends have a different flare from those of the sides, and in one case the folded corners are to be bent toward the end, while it may be required that the corners be folded towards the side. The principles are similar in both cases, but as the method of applying these principles may be a little difficult, Fig. 28 has been prepared, which will explain the application of these principles.

First draw the side elevation, showing the desired flare; also draw the end elevation, which shows the flare of the sides, being careful that the vertical heights in both views are the same. Now draw the pattern of the pan as follows: Take the distance 1–2 in side elevation and place it on the ends of the bottom as shown on either side by 1′–2′. Similarly take the distance 3–4 in end elevation and place it on the sides of the bottom as shown on either side by 3′–4′. Through the point 2′ and 4′ draw lines parallel to the ends and sides of the bottom as shown, which intersect lines dropped from the end and side views respectively. hfh' represent the butt miters which should be placed on all corners. If these miters have been correctly developed, the lengths from h to f must be equal to fh'. Bisect the angle hfh' by using f as center and drawing the arc ab, then use a and b as centers and obtain the intersection c, through which draw the line cf. Now assume that the folded corner is to be turned towards the end view as shown by $t3$. Using h as a center draw the arc ij. Then with l as center and li as radius, intersect the arc ij at m. Draw a line from h through m, meeting the line cf at t, and draw a line from t to h'.

If the folded corner were turned towards the side as shown by r'–$2''$ in the side view, bisect the angle $v1's$ as before, and use s as a center and proceed as already explained. Note the difference in the two corners. The only point to bear in mind is, that when the corner is to be folded towards the end, transfer the angle of the end miter; while if the corner is to be turned towards the side, transfer the angle of the side miter. If the corners were to be folded toward the ends of the pan, the cut shown in the right-hand corner would be used on all four corners, while if the corners were to be folded towards the sides, the cut shown on the left-hand corner would be used.

Tea Pot. In Fig. 29 is shown the well-known form of the tea or coffee pot, for which a short method of developing the pattern is shown in Fig. 30. This is one of the many cases where a short rule can be used to advantage over the geometrical method. While it is often advisable to use the true geometrical rule, the difference between that and the method here shown is hardly noticeable in practice. Of course, if the body A and spout B were larger than the ordinary tea pots in use, it would be necessary to use the true geometrical rule, which is thoroughly explained for Plates I, II and III.

Fig. 29.

The pattern for the body of the tea pot will not be shown, only the short rule for obtaining the opening in the body to admit the joining of the spout. The method of obtaining the pattern for the body is similar to the flaring vessels shown in previous problems.

First draw the elevation of the body of the tea pot as shown at A. Assume the point a on the body and draw the center line of the spout at its proper angle as shown by $2b$. Establish the point 3 of the bottom of the spout against the body, also the point 3^x at the top and draw a line from 3 through 3^x intersecting the center line at b. At right angles to the center line and from 3 draw the line $3-1$ and make $c1$ equal to $c3$. From 1 draw a line to the center point and from 3^x draw a horizontal line until it intersects the opposite side of the spout at $1''$. Then $1'-1''-3^x-3$ will be the side view of the spout. Now with c as a center draw the half section 1–2–3 and divide it into equal spaces; in this case but two (in practical work more spaces should be employed). From these points and at right angles to $1-3$ draw lines intersecting the base of the spout as shown, and draw lines from these points to the center b. Thus line $1b$ intersects the body at $1'$ and the top of the spout at $1''$; line $2b$ intersects the body at a and the top of the spout as shown, while line $3b$ cuts at 3 and the top of spout at 3^x. From these intersections at right angles to the center line ab, draw lines intersecting the side of the spout at 3, 2°, 1° at the bottom and 1^x, 2^x, 3^x at the top. Now with b as center and $b3$ as radius, describe the arc $3''-3''$ upon which place the stretchout of twice the number of spaces contained in the half section 1 – 2 – 3, as shown by similar figures on $3'' - 3''$; from these points draw radial lines to the center *b*, and intersect them by arcs drawn with *b* as a center and radii equal to the intersections contained on the side of

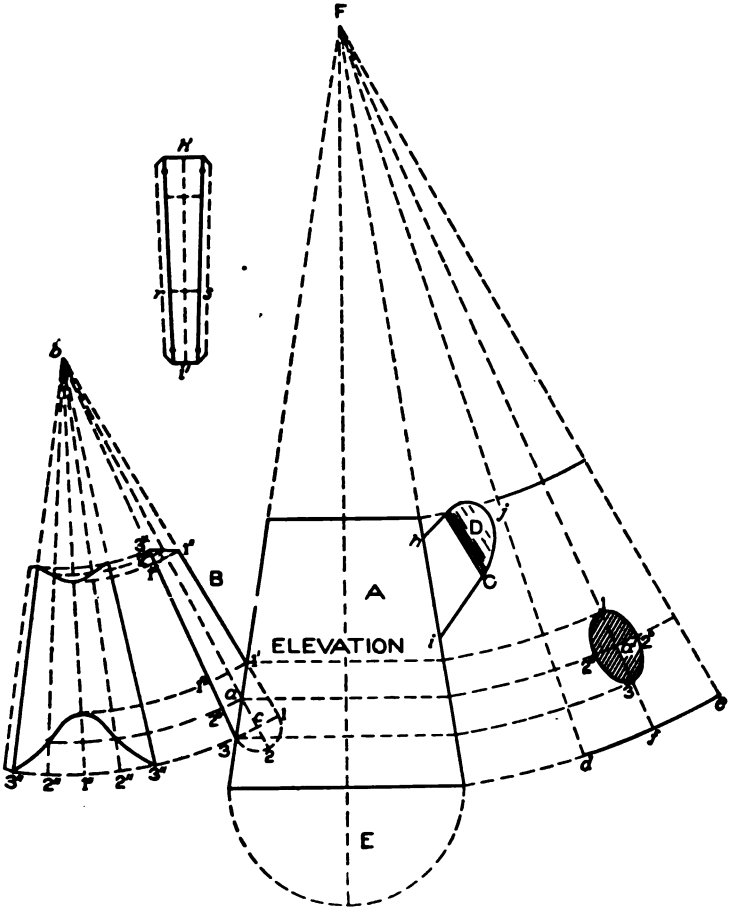


Fig. 30.

the spout $3 - 3^x$. To form the pattern, trace a line through points thus obtained and make the necessary allowance for edges.

It should be understood that in thus developing the spout, the fact that the spout intersects a round surface has not been considered; it was assumed to intersect a plane surface. As already stated the difference in the pattern is so slight that it will not be noticeable in practice. Had we developed the pattern according to the true geometrical rule, it would present a problem of two cones of unequal diameter intersecting each other, at other than at right angles to the axes.

For the pattern for the opening in the body, draw lines at right angles to the center line of the body from intersections 1′, *a* and 3 intersecting the opposite side of the body as shown. With F as a center draw a partial pattern of the body as shown by *dc*. From any point *f* draw a line to the center F. Now with F as center draw the arcs 1, 2° and 3. The distance 1 to 3 on the line F*f* represents the length of the opening, while a line drawn through *a* at right angles to the center line *bc* of the spout represents the width of the opening. Therefore take the distance from *a* to 2° and place it as shown from *a*′ on the line *f*F to 2° – 2° on either side on the arc. Trace an ellipse through 1 – 2° – 3 – 2° for the shape of the opening.

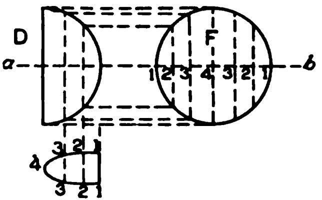


Fig. 31.

The pattern for the handle is obtained by taking the stretchout of *hji* and placing it as shown on the vertical line *h*′*i*′. At right angles to *h*′*i*′ on either side, at top and bottom add the desired width of the handle and draw the lines shown; add edges for wiring or hem edge.

For the pattern for the grasp D which is placed inside on the handle proceed as is shown in Fig. 31. Let D represent an enlarged view of part of the handle in which the grasp is to be soldered. Directly in line with it draw the section E taking care that the width from 1 to 1 will not be wider than that portion of the handle from *r* to *s* in Fig. 30, being the width at C in the elevation. Divide the section E in Fig. 31 into a number of equal spaces, from which draw vertical lines intersecting the curve D as shown. Draw the center line *ab* upon which lay off the stretchout of E as shown by similar figures. Through these points draw lines which intersect with lines drawn from similar intersections in the curve D parallel to *ab*. Trace a line through the points thus obtained as shown at F.

Foot Bath. In Fig. 32 is shown an oval foot bath; the principles used in obtaining the pattern of which are applicable to any form of flaring vessels of which the section is elliptical or struck from more than two centers. In this connection it may be well to explain how to construct an ellipse, so that a set of centers can be obtained with which to strike the arcs desired. Fig. 33 shows the method of drawing an approximate ellipse, if the dimensions are given. Let AB represent the length of the foot bath and CD its width. On BA measure BE equal to CD. Now divide the distance EA into three equal parts as shown by 1 and 2. Take two of these parts as a radius, or E2, and with O as center, describe arcs intersecting the line BA at X and X^1. Then with XX^1 as a radius and using X and X^1 as centers describe arcs intersecting each other at C and D. Draw lines from C to X and X^1 and extend them toward F and G respectively. Similarly from D draw lines through X and X^1, extending them towards I and H respectively. Now with X and X^1 as centers, and XA and X^{1}B as radii describe arcs intersecting the lines ID, FC, GC and HD at J, K, L and M, respectively. In similar manner

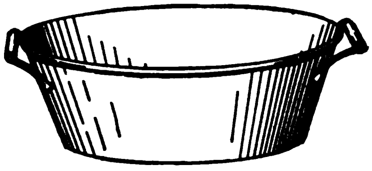


Fig. 32.

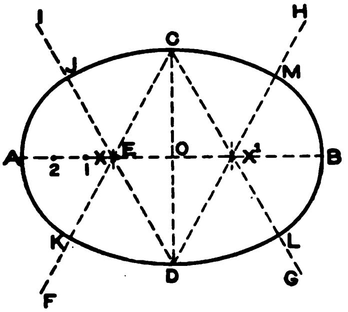


Fig. 33.

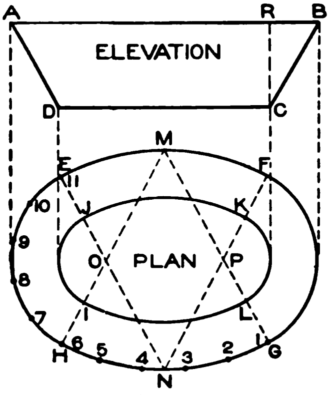


Fig. 34.

with D and C as centers and DC and CD as radii describe arcs which must meet the arcs already drawn at J, M, L and K, respectively, forming an approximate ellipse. In Fig. 34 let ABCD represent the side elevation of the pan, whose vertical height is equal to RC.

In precisely the same manner as described in Fig. 33 draw the plan as shown, in correct relation to the elevation, letting EFGH be the plan of the top of the pan, and JKLI the plan of the bottom, struck from the centers, O,M,P and N. The next step is to obtain the radii with which to strike the pattern. Draw a horizontal line RE in Fig. 35 equal in length to NE in plan in Fig 34. Take the vertical height RC in elevation, and place it as shown by RC in Fig. 35 on a line drawn at right angles to RE. Parallel to RE and from the point C, draw the line CJ equal to NJ in Fig. 34.

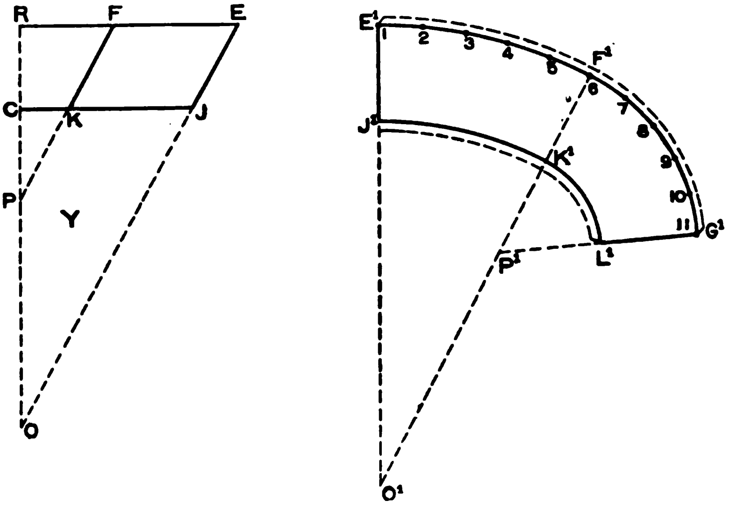


Fig. 35.

Now draw a line from E to J in Fig. 35, extending it until it meets the line RC produced. Then OJ and OE will be the radii with which to make the pattern for that part of the pan or foot bath shown in plan in Fig. 34 by EFKJ and GHIL.

To obtain the radii with which to strike the smaller curves in plan, place distances PF and PK on the lines RE and CJ in Fig. 35 as shown by RF and CK. Draw a line from F through K until it meets the line RO at P. Then PK and PF will be the radii with which to strike the pattern, for that part shown in plan in Fig. 34 by KFGL and IHEJ. Now divide the curve from G to H and H to E (Fig. 34) into a number of equal spaces. To describe the pattern draw any vertical line E^1O^1 (Fig. 35) and with O^1 as center and radii equal to OJ and OE in the diagram Y, describe the arcs J^1K^1 and E^1F^1 as shown. On the arc E^1F^1 lay off the stretchout of GH in plan in Fig. 34 as shown by similar figures in Fig. 35. From the point 6 on the arc E^1F^1 draw a line to O^1 intersecting the curve J^1K^1. Now with PF in diagram Y as radius and F^1 as a center describe an arc intersecting the line F^1O^1 at P^1. Then using P^1 as a center and with radii equal to P^1K^1 and P^1F^1 describe the arcs K^1L^1 and F^1G^1 as shown. On the arc F^1G^1 starting from point 6 lay off the stretchout of HE, Fig. 34. From 11 draw a line to P^1 intersecting the arc K^1L^1 at L^1. Then $E^1F^1G^1L^1K^1J^1$ will be the half pattern, the allowance for wiring and seaming being shown by the dotted lines.

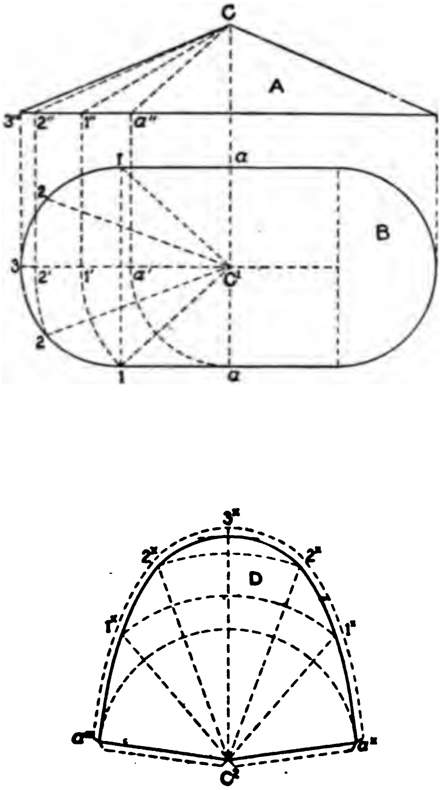


Fig. 37.

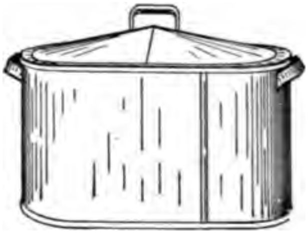


Fig. 36.

Should the article be desired in four sections, two pieces of $F^1K^1L^1G^1$ would be required. The pattern for the bottom of the pan is shown by the inner ellipse in Fig. 34 to which of course edges must be allowed for double seaming.

Wash Boiler. In Fig. 36 is shown a perspective view of a wash boiler to which little attention need be given, except to the raised cover. First draw the plan of the cover B, Fig. 37, which shows straight sides with semi-circular ends. In line with the plan draw the elevation A, giving the required rise as at C. Let C represent the apex in elevation, and C^1 the apex in plan. As both halves of the cover are symmetrical, the pattern will be developed for one half only. Divide the semi-circle 1 – 3 – 1 into a number of equal spaces as shown by the small figures 1, 2, 3, 2 and 1. From these points draw radial lines to the apex C^1, and through C^2 draw the perpendicular *aa*. C3″ in elevation represents the true length of $C^1$3 in plan, and to obtain the true length of $C^1$2, $C^1$1 and C^1a, it will be necessary to construct a diagram of triangles as follows: With C^1 as center, and C^1a, $C^1$1 and $C^1$3 as radii, describe arcs intersecting the center line in plan at *a*′, 1′ and 2′. From these points at right angle to $3C^1$ erect lines intersecting the base line of the elevation at *a*″, 1″, 2″ and 3″, from which draw lines to the apex C, as shown. Now, with radii equal to C3″, C2″, C1″ and C*a*″, and C^2 as center describe arcs 3^x,2^x2^x, 1^x1^x and a^xa^x. From C^2 erect the perpendicular intersecting the arc 3^x at 3^x. Now set the dividers equal to the spaces 3 to 2 to 1 to *a* in plan, and starting from 3^x step off to similar numbered arcs, thus obtaining the intersections $2^x1^xa^x$; from a^x draw lines to C^2, and trace a line $a^x3^xa^x$ to get the half pattern for the cover. Allow edges for seaming.

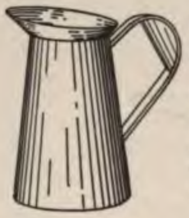


Fig. 38.

The body of the boiler requires no pattern, as that is simply the required height, by the stretchout of the outline shown in plan. The handles shown on the body and cover in Fig. 36 are plain strips of metal to which wired or hem edges have been allowed.

Measure. Fig. 38 shows a flaring-lipped measure with handle attached. Care should be taken in laying out the patterns for these measures, that when the measure is made up it will hold a given quantity. While there are various proportions used in making up the size of the measure, the following table gives good proportions:

Quantity.	Bottom Diameter in inches.	Top Diameter in inches.	Height.
1 Gill.	2.06	1.37	3.10
½ Pint.	2.60	1.75	3.89
1 Pint.	3.27	2.18	4.90
1 Quart.	4.12	2.75	6.18
½Gallon.	5.18	3.45	7.78
1 Gallon.	6.55	4.35	9.80

Fig. 39 shows the method of laying out the pattern for the measure and lip. First draw the elevation A to the desired size

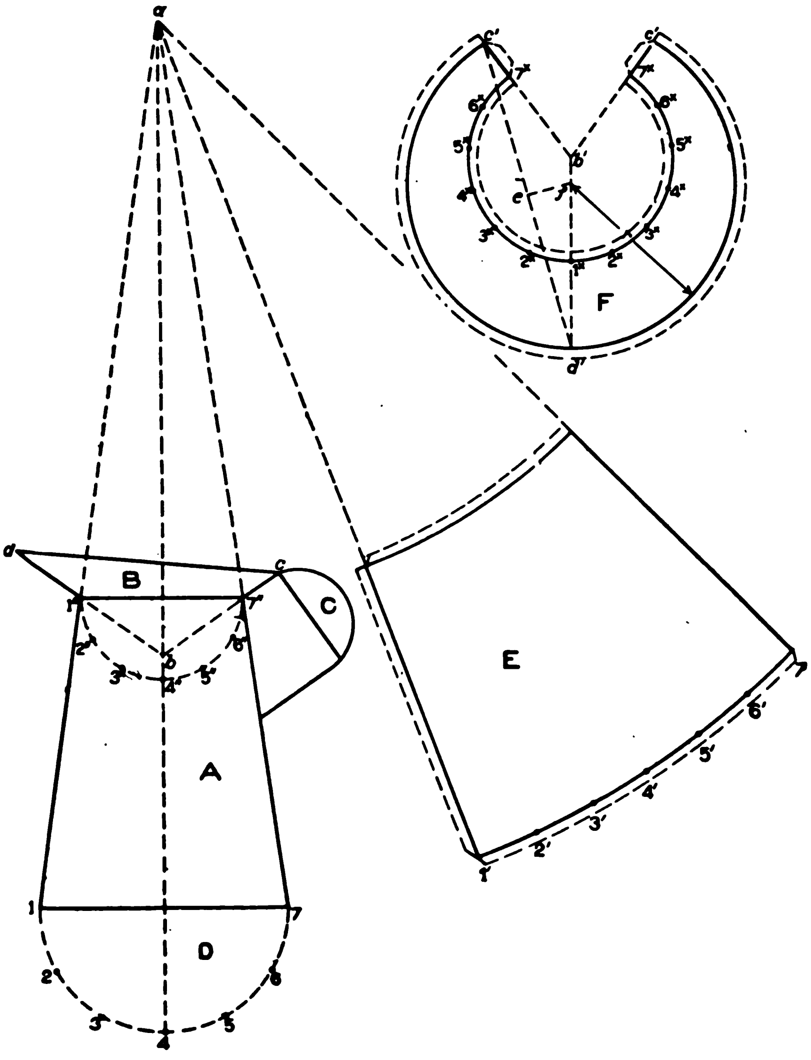


Fig. 39.

and assume the flare of the lip B, as shown by *db*. From *b* draw a line through 7" to *c* which is a chosen point, and draw a line from *c* to *d*. Draw the handle C of the desired shape. Now extend contour lines of the measure until they intersect at *a*, and draw the half section of the bottom of the measure as shown at D; divide this semi-circle into equal parts as shown. Now, with a as a center, and $a7$ and $a7''$ as radii, describe the arcs as shown. From any point (as $1'$) draw a radial line to a, and starting at $1'$ set off the number of spaces contained in the half section D, as shown by the small figures $1'$ to $7'$. From $7'$ draw a radial line to a. Allow edges for wiring and seaming. E represents the half pattern for the body of the measure. We find that lip B is simply an intersected frustum of a right cone, which can be developed as shown in the pattern for conical boss of Fig. 25.

There is, however, a shorter method which serves the purpose just as well; this is shown at F, Fig. 39. First draw the half section of the bottom of the lip, which will also be the half section of the top of the measure, as shown by the figures $1''$ to $7''$. Now, with radii equal to $b-1''$, or $b-7''$ and b' in F as center, describe the arc 7^x7^x. From b' drop a vertical line intersecting the arc at 1^x. Starting from the point 1^x, set off the spaces contained in the half section $1''-4''-7''$, as shown by the figures 1^x to 7^x. From b' draw lines through the intersections 7^x7^x, extending them as shown. Now take the distance from $1''$ to d of the front of the lip and place it as shown by $1^xd'$ in F. In similar manner take the distance from $7''$ to c of the back of the lip and place it as shown in F from 7^x to c' on both sides. Draw a line from c' to d', and bisect it to obtain the center e. From e, at right angles to $c'd'$, draw a line intersecting the line $b'd'$ at f. Then using f as center, with radius equal to fd', draw the arc $c'd'c'$, as shown. Adding laps for seaming and wiring will complete the pattern for the lips.

The pattern for the handle and grasp C is obtained as shown in Figs. 30 and 31.

Scale Scoop. Fig. 40 shows a scale scoop, wired along the top edges and soldered or seamed in the center. The pattern is made as shown in Fig. 41. First draw the elevation of the scoop as shown by ABCD. (In practice the half elevation, BDC, is all that is necessary.) At right angles to BD and from the point C, draw the indefinite straight line CE, on which a true section is to be drawn. Therefore, at right angles to CE, from points C and E, draw the lines CC and EE^1. From E^1 erect a perpendicular as E^1C, on which at a convenient point locate the center F; with

FE^1 as radius, describe the arc HE^1I. Then HE^1I will be the true section on CE in elevation. Divide the section into a number of equal parts as shown by the figures 1 to 7; through these points, parallel to the line of the scale BD, draw lines intersecting BC and CD as shown. At right angles to BD draw the stretchout line 1 – 7 and place upon it the stretchout of the section as shown by similar figures. At right angles to 1 – 7 draw lines which intersect lines drawn at right angles to BD, from intersections on BC and DC having similar numbers. Trace a line through these points and thus obtain the desired pattern. The dotted outline shows the lap and wire allowance.

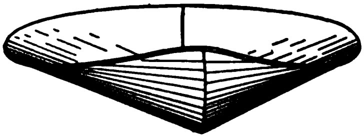


Fig. 40.

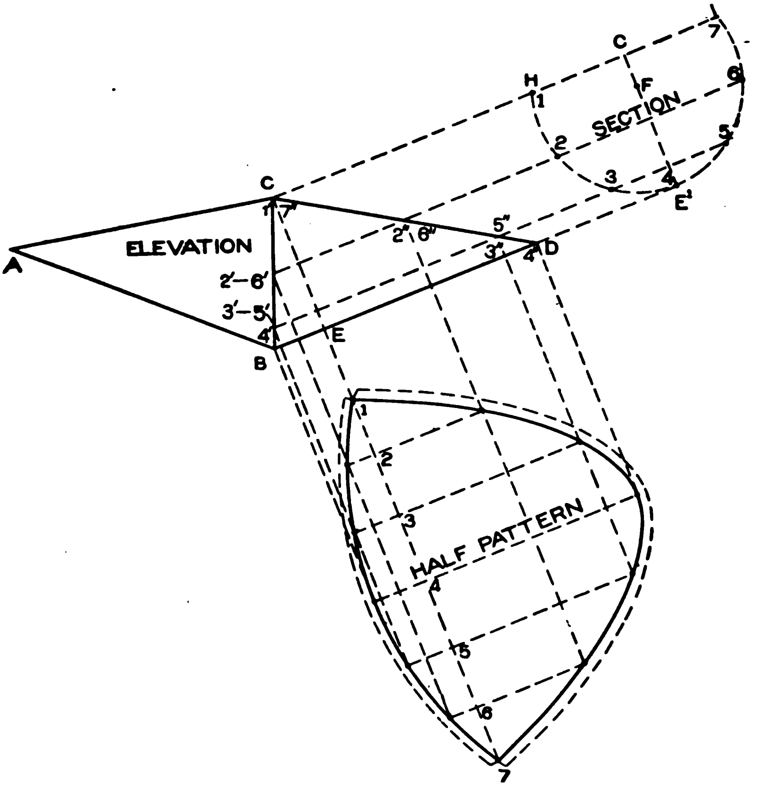


Fig. 41.

In Fig. 42 is shown a perspective view of a **dust pan** with a tapering handle passing through the back of the pan and soldered to the bottom. The first step is to draw the plan and elevation which is shown in Fig. 43. Let ABC be the side view of the pan. Directly below it, in its proper position, draw the bottom DEFG. From the point C in elevation draw a line *d'd* indefinitely. Now bisect the angle EFG. Through *c* and F draw the line *cd*, intersecting the line *dd'* at *d*. From *d* draw a line to G.

In the same manner obtain E*d'*D on the opposite side, which will complete the plan view of the pan. Now locate the point *h* in side view, through which the center line of the handle shall pass, and draw the line *lm* Through *m*, the end of the handle, draw the line *no* at right angles to *lm*, and assume *o* the half width at the top and *j* the point where the contour line of the handle shall meet the back of the pan, and draw a line from *o* through *j*, intersecting the center line *lm* at *l*. Make *mn* equal to *mo* and draw a line from *n* to *l*, intersecting the back of the pan at *x*. Through *h* at right angles to the center line draw *ij''*, giving the diameter of the handle at that point to be used later. This completes the elevation of the handle; the plan view is shown by dotted lines and similar letters, but is not required in developing the pattern.

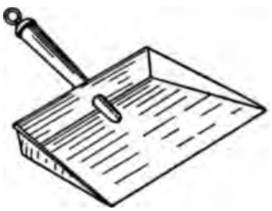


Fig. 42.

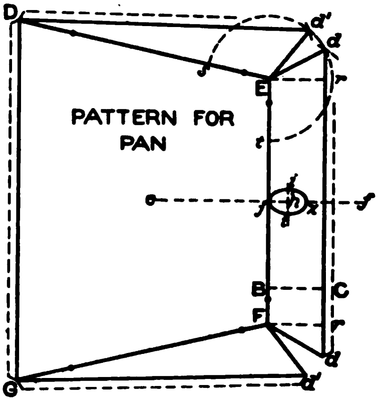


Fig. 44.

For the pattern of the pan proceed as is shown in Fig. 44, in which DEFG is a reproduction of similar letters of Fig. 43. Take the distance of BC in side view, Fig. 43, and place it as shown by

BC in Fig. 44 and through C draw a line parallel to EF as shown. At right angles to and from EF draw E*r* and F*r*, then take the distance from *r* to *d* in plan in Fig. 43 and place it as shown from *r* to *d* on both sides in Fig. 44. Draw the lines *d*F and *d*E. Now using E as center, and radius equal to E*d* describe the arc *st*. Then with *td* as radius and *s* as center, intersect the arc *st* at *d'*. Draw a line from *d'* to D. In similar manner obtain *d'*G on the opposite side, which will complete the pattern for the pan. Allow laps for wiring and edging.

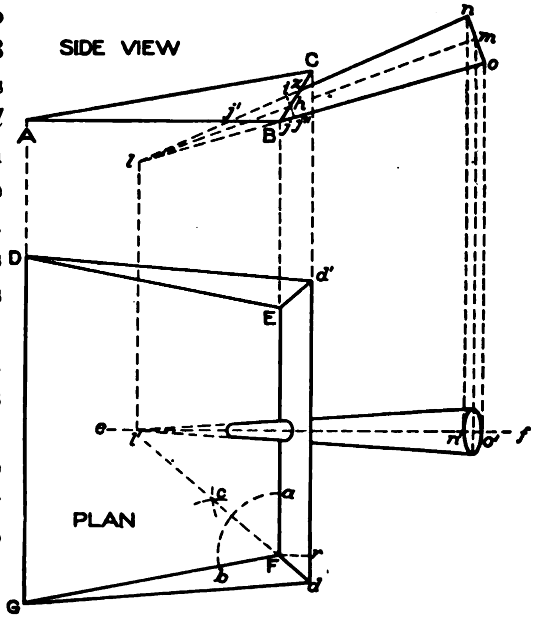


Fig. 43.

The opening in the back of the pan to allow the handle to pass through is obtained by first drawing a center line *ef*, then take the distances from *j* to *h* and *h* to *x* in Fig 43, noting that *j* comes directly on the bend B, and place it in Fig. 44 on the line *ef*

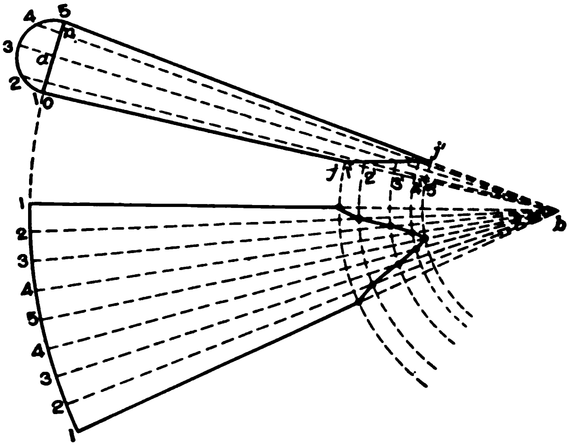


Fig. 45.

from *j* to *h* to *x*, placing *j* on the bend as shown. Now take the distance from *h* to *i* or *h* to *j''* in side view in Fig. 43 and place it in Fig. 44 from *h* to *i* on either side; on a line drawn through the points *jixi* draw an ellipse shown. Fig. 45 shows the method of drawing the pattern for the tapering handle. From the figure we find that we have a frustum of a right cone. To illustrate each step the handle has been slightly enlarged. *n*, *o*, *j*, *j'* represents *n*, *o*, *j*, *j'* in Fig. 43. Draw the half section in Fig. 45 as shown. and divide it into equal parts; drop perpendiculars as shown to the line *no*, and from these points draw lines to the apex *b*, which is obtained by extending the lines *nj'* and *oj* until they meet at *b*. Where the radial lines intersect the line *jj'* draw lines at right angles to the center line 3b, intersecting the side of the handle *o b* at 1', 2', 3', 4' and 5'. Now with *b* as a center and *bo* as a radius, describe the arc 1–1, upon which place twice the number of spaces contained in the half section *a*. From these points on 1–1 draw radial lines to *b* and cut them with arcs struck from *b* as center and radii equal to *b*1', *b*2', *b*3', *b*4' and *b*5'. Trace a line through points thus obtained to complete the pattern.

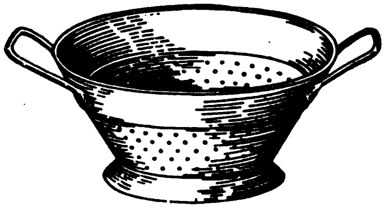


Fig. 46.

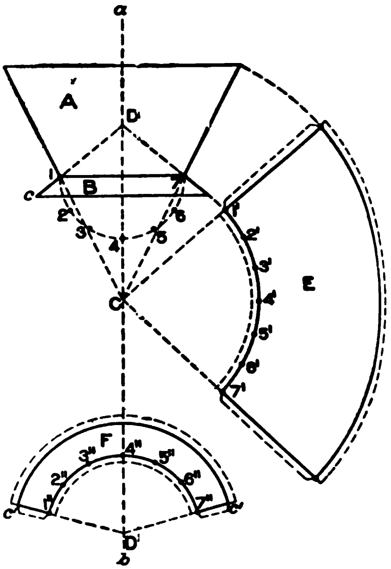


Fig. 47.

Colander. Fig. 46 shows another well-known form of tin ware, known as a colander. The top and bottom are wired and the foot and body seamed together, the handles of tinned malleable iron being riveted to the body. In Fig. 47 is shown how to lay out the patterns. Draw the elevation of the body A and foot B and extend the sides of the body and foot until they meet respec tively at C and D on the center line *ab*. Draw the half section on the line 1–7 and divide it into equal parts as shown. For the body, use C as a center and describe the arcs shown, laying off the stretchout on the lower arc, allowing edges in the usual manner. Then E will be the half pattern for the body. In the usual manner obtain the pattern for the foot shown at F, the pattern being struck from D^1 as center, with radii obtained from the elevation D1 and D*c*.

TABLE OF STANDARD OR REGULAR TIN PLATES.

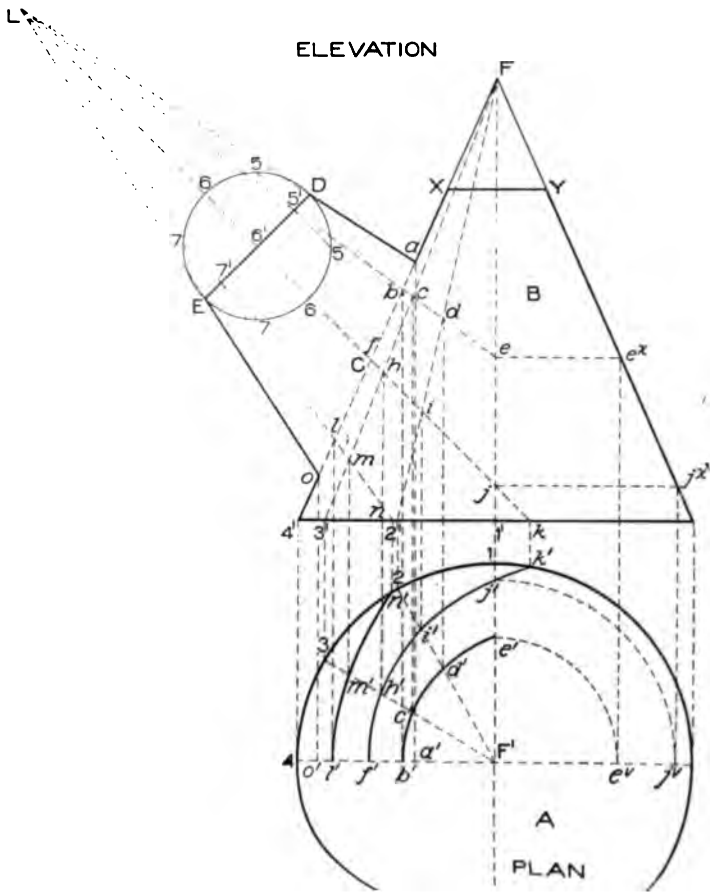
Size and Kind of Plates, Number and Weight of Sheets in a Box, and Wire Guage Thickness, of Every Kind and Size.

Size.	Grade.	Sheets in Box.	Pounds in Box.	Wire Guage.
10 x 10	IC	225	80	29
"	IX	225	100	27
"	IXX	225	115	26
"	IXXX	225	130	25
"	IXXXX	225	145	24 1-2
10 x 14	IC	225	112	29
"	IX	225	140	27
"	IXX	225	161	26
"	IXXX	225	182	25
"	IXXXX	225	203	24 1-2
"	IXXXXX	225	224	24
"	IXXXXXX	225	245	23 1-2
10 x 20	IC	225	160	29
"	IX	225	200	27
11 x 11	IC	225	95	29
"	IX	225	121	27
"	IXX	225	139	26
"	IXXX	225	157	25
"	IXXXX	225	175	24 1-2
11 x 15	SDC	200	168	26
"	SDX	200	189	25
"	SDXX	200	210	24 1-2
11 x 15	SDXXX	200	230	24
12 x 12	IC	225	112	29
"	IX	225	140	27
"	IXX	225	161	20
"	IXXX	225	182	25
"	IXXXX	225	203	24 1-2
"	IXXXXX	225	224	24
"	IXXXXXX	225	245	23 1-2
12 1-2 x 17	DC	100	98	28
"	DX	100	126	26
"	DXX	100	147	24
"	DXXX	100	168	23
"	DXXXX	100	189	22
"	DXXXXX	100	210	21
13 x 13	IC	225	135	29
"	IX	225	169	27
"	IXX	225	194	26
"	IXXX	225	220	25
"	IXXXX	225	245	24 1-2
13 x 17	IXX	225	254	26
13 x 18	IX	225	234	27
"	IXX	225	269	26
14 x 14	IC	225	157	29
"	IX	225	196	27
"	IXX	225	225	26
"	IXXX	225	255	25

TABLE OF STANDARD OR REGULAR TIN PLATES.---Con.

Size.	Grade.	Sheets in Box.	Pounds in Box.	Wire Gauge.
14 x 14	IXXXX	255	284	24 1-2
14 x 17	IX	225	238	27
14 x 20	IC	112	113	29
"	IX	112	143	27
"	IXX	112	162	26
"	IXXX	112	183	25
"	IXXXX	112	202	24 1-2
15 x 15	IX	225	225	27
"	IXX	225	259	26
"	IXXX	225	293	25
"	IXXXX	225	326	24 1-2
15 x 21	IX	112	158	27
"	DXX	100	218	24
"	DXXX	100	249	23
"	DXXXX	100	280	22
15 x 22	IXX	112	190	26
"	SDXX	100	210	24 1-2
"	SDXXX	100	230	24
16 x 16	IC	225	205	29
"	IX	225	256	27
"	IXX	225	294	26
"	IXXX	225	333	25
"	IXXXX	225	371	24 1-2
17 x 17	IC	225	231	29
17 x 17	IX	225	289	27
"	IXX	112	166	26
"	IXXX	112	188	25
"	IXXXX	112	210	24 1-2
17 x 25	DC	100	196	28
"	DX	100	252	26
"	DXX	50	146	24
"	DXXX	50	168	23
"	DXXXX	50	189	22
"	IX	112	213	27
"	IXX	112	244	26
18 x 18	IX	112	162	27
"	IXX	112	186	26
"	IXXX	112	211	25
"	IXXXX	112	235	24 1-2
19 x 19	IC	112	144	29
"	IX	112	180	27
"	IXX	112	207	26
"	IXXX	112	234	25
"	IXXXX	112	262	24 1-2
20 x 20	IC	112	160	29
"	IX	112	200	27
"	IXX	112	230	26
"	IXXX	112	260	25
"	IXXXX	112	290	24 1-2
20 x 28	IC	112	224	29
"	IX	112	280	27
"	IXX	112	322	26

PLATE I


L
ELEVATION
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e'
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j^v
A
PLAN

EXAMINATION PLATES.

Drawing Plates I to IV inclusive constitute the examination for this Instruction Paper. The student should draw these plates in ink and send them to the School for correction and criticism. The construction lines and points should be clearly shown. The date, student's name and address, and plate number should be lettered on each plate in Gothic capitals.

In preparing the plates, the student should practice on other paper, and then send finished drawings for examination. The plates of this instruction paper should be laid out in the same manner and of the same size as the plates in Mechanical Drawing Parts I, II and III.

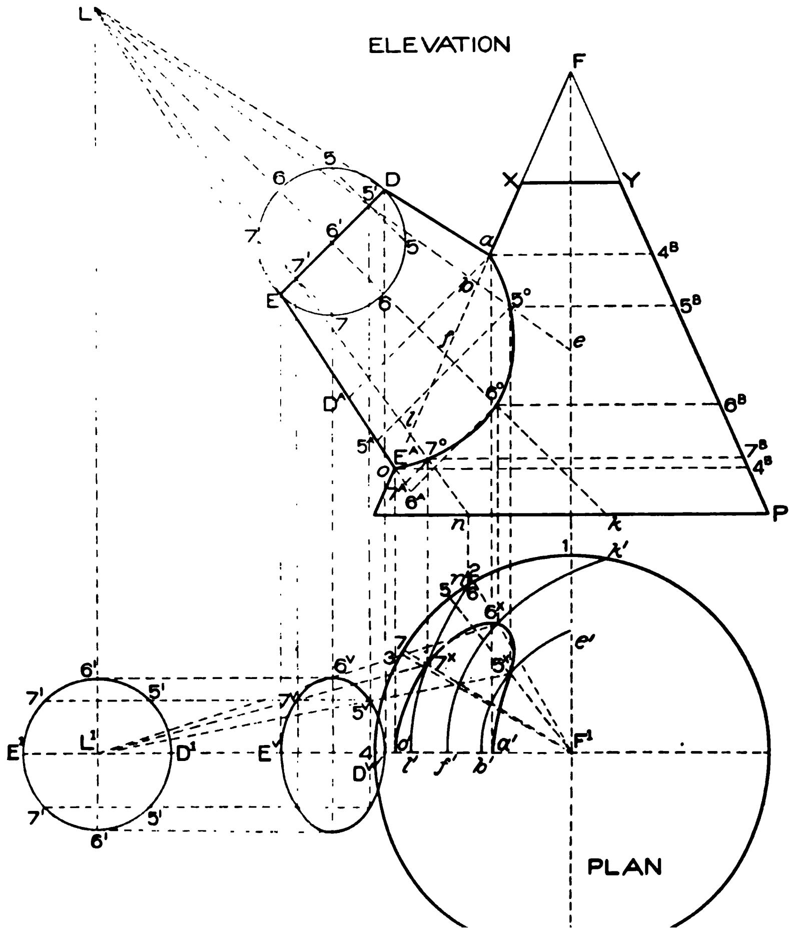
PLATE I.

On this plate, the intersection between two right cones is shown. This problem arises in the manufacture of tinware in such instances as the intersections between the spout and body as in a teapot, watering pot, kerosene-oil can, dipper handle and body, and other articles. It is one of the most complicated problems arising in tinsmith work. The problem should be drawn in the center of the sheet making the diameter of the base A 4 inches and the height of the cone B $4\frac{1}{2}$ inches. The distance from X to Y should be 1 inch. From the point F measure down on the side of the cone a distance of $3\frac{1}{8}$ inches and locate the point C, from which draw the axis of the smaller cone at an angle of 45° to the axis of the larger cone. From C measure on CL $1\frac{5}{8}$ inches locating the point 6'; through this point, at right angles to the axis, draw ED equal to $1\frac{1}{2}$ inches. From the point 4' on the base of the cone, measure up on the side of the cone a distance of $\frac{1}{2}$ inch as indicated by *o*, and draw a line from *o* to E, extending it, until it intersects the axis LC at L. From L draw a line through D extending it until it intersects the larger cone at *a*. Then D *a o* E will represent the outline of the frustum of the smaller cone in elevation.

The next step is to obtain the line of intersection between the two cones, but before this can be accomplished, horizontal sections must be made through various planes of the smaller cone cutting into the larger. As the intersection of each half of the smaller cone with the larger one is symetrical, and as the small cone will not intersect the larger one to a depth greater than the point 1 in plan, divide only one-quarter of the plan into a number of equal spaces as shown by figures 1 to 4; from these points draw radial lines to the center F^1 as shown. Also from points 1, 2, 3 and 4 erect vertical lines intersecting the base of the cone at 1′, 2′, 3′ and 4′ respectively, from which points draw radial lines to the apex F.

Now with 6′ on the line ED as a center describe the circle shown, which represents the true section on ED. Divide each semi-circle into the same number of divisions as shown by the small figures D, 5, 6, 7, and E on either side. From these points at right angles to ED draw lines intersecting the center line ED at 5′. 6′ and 7′. From the apex L draw lines through the intersection 5′, 6′ and 7′, and extend them until they intersect the axis of the large cone at *e* and the base line at *k* and *n*. The student may naturally ask why the radial lines in the small cone are drawn to these points. As it is not known how far the smaller cone will intersect the larger one, we obtain such sections on the planes just drawn, as we think will be required to determine the depth of the intersection. Thus the radial line drawn through 5′ intersects the radial lines through 4′, 3′, 2′ and 1′ in the larger cone, at *b*, *c*, *d* and *e* respectively. The radial line through 6′ intersects radial lines in the larger cone at *f*, *h*, *i*, *j* and the base line at *k*, while the radial line drawn through the point 7′, intersects the radial lines of the larger cone at *l* and *m* and the base at *n*. We know that the line D*a* and E*o* of the smaller cone intersect the larger cone at points *a* and *o* respectively, and determine the true points of intersection; these are shown in plan by *a*′ and *o*′, and therefore no horizontal sections are required on these two planes. For the horizontal section on the plane *b c*, drop vertical lines from the intersections *b*, *c* and *d* on the radial lines, intersecting radial lines having similar numbers in plan as shown by *b*′, *c*′ and *d*′. To obtain the point of intersection in plan of *e* in elevation, draw from the point *e* a horizontal line intersecting the side of the cone at e^x, from which point drop a perpendicular line intersecting the center line in plan at e^v.

PLATE II


ELEVATION
PLAN
L
F
X
Y
D
E
a
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f
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n
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P
1
k'
e'
F¹
a'
b'
f'
l'
D'
E'
L'
D^v
E^v
4^B
5^B
6^B
7^B
5°
6°
7°
5
6
7
5'
6'
7'
6^x
5^x
7^x
6^v
5^v
7^v
2
3
4

Then using F^1e^v as radius, describe an arc intersecting the radial line 1 at *e'*. Through the points *e'*, *d'*, *c'* and *b'* draw a curved line, which is the half horizontal section of *b e* in elevation. In the same manner obtain the sections shown in plan by *f'*, *h'*, *i'*, *j'* and *k'*; and *l'*, *m'* and *n'*, which have similar letters and figures in both plan and elevation. The next step is to obtain the intersections where the radial lines of the smaller cone will intersect these sections in plan just obtained. To avoid a confusion of lines which would otherwise occur, a reproduction of the plan and elevation has been transferred to Plate II.

PLATE II.

The figures on this plate are similar to those on Plate I and have similar letters and figures; those letters and figures being omitted which are not necessary. This plate should be studied carefully before proceeding. The reproducing from Plate I can be best done by using a needle point or the small needle which is usually found in the handle of the drawing pen, when unscrewing the pen from the handle, and pricking through Plate I, very small indistinct prick marks. Omit all that is omitted in Plate II, where it will be noticed that the radial line in elevation, of the larger cone, and some of the various small letters in plan are not represented.

To obtain the plan view of the smaller cone, proceed as follows: Extend the line F^1 4 in plan as shown by F^1 E^1. From the apex L of the smaller cone drop a vertical line intersecting F^1 E^1 at L^1, which represents the apex of the smaller cone in plan. With L^1 as center and radius equal to the radius 6' D describe the circle E^1 D^1 and divide the circumference into the same number of spaces as ED, being careful to number the spaces as is there shown. The reason for doing this may be better understood from what follows: Assume that ED is a pivot on which the circle turns, so that it lies on a plane ED, then by looking down from the top, the points 6 and 6 appear as shown by 6' and 6' in plan.

A better illustration is obtained by cutting a card-board disc and after spacing it and numbering the points hold it in various positions until all the points become clear. Now from the intersections on ED in elevation, drop lines, intersecting horizontal lines drawn from similar numbered points in the profile E^1 D^1, thus obtaining the points of intersection D^v, 5^v, 6^v, 7^v and E^v. Trace a curved line through these points, which will give the the top view of ED. As the radial lines drawn through the points $5'$, $6'$ and $7'$ on the line ED of the smaller cone in elevation intersect the section lines *b e*, *f k* and *l n* respectively, the radial lines in plan drawn through the apex L^1 and points 5^v, 6^v, and 7^v must intersect similar section lines in plan $b' e'$, $f' k'$ and $l' n'$ respectively, as shown by points 5^x, 6^x and 7^x. The points a' and o' are obtained by dropping perpendiculars from the points *a* and *o* in elevation onto the line E^1 F^1 in plan. Through the points thus obtained, draw the curved line a', 5^x, 6^x, 7^x, o' which will represent the plan view of one-half of the intersection between the two cones, the other half being similar.

Now from the intersections 5^x, 6^x and 7^x on the section lines $b' e'$, $f' k'$ and $l' n'$ respectively, erect perpendicular lines intersecting similar section lines in elevation *b e*, *f k* and *l n* as shown respectively by points 5°, 6° and 7°.

A curved line traced through *a*, 5°, 6°, 7° and *o* will represent the line of intersection between the two cones in elevation. At right angles to the axis of the smaller cone and from the intersections *a*, 5°, 6° and 7° draw lines intersecting the side of the cone E *o* at D^A 5^A 6^A and 7^A. For the pattern of the smaller cone proceed as is shown in the following plate:

PLATE III.

On this plate the two patterns should be placed in the center of the sheet. Take the radius of LD in Plate II and with L in Fig. 1 of Plate III as center describe the arc DD. From L drop a vertical line as shown by L E^A. Upon the arc DD measuring from either side of the point E, lay off the stretchout of the semi-circle E, 7, 6, 5, D in Plate II as shown by similar letters and figures on DD in Fig. 1 Plate III. From the apex L and through these points draw radial lines as shown and intersect them by arcs whose radii are equal to L D^A, L 5^A, L 6^A, L 7^A and L E^A in Plate II, as shown by similar letters and figures in Plate III. Trace a line through points thus obtained, and D, E, D, D^A, E^A, D^A, D will be the pattern for the small cone. As the pattern for the larger cone is obtained in the usual manner, we will only show how to obtain the opening to be cut into one side of the larger

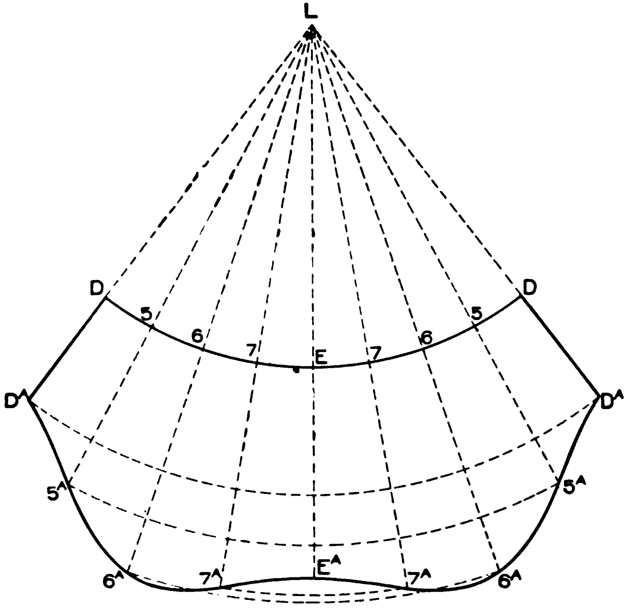

L
D
D
5
6
7
E
7
6
5
D^A
D^A
5^A
5^A
6^A
7^A
E^A
7^A
6^A

FIG. 1

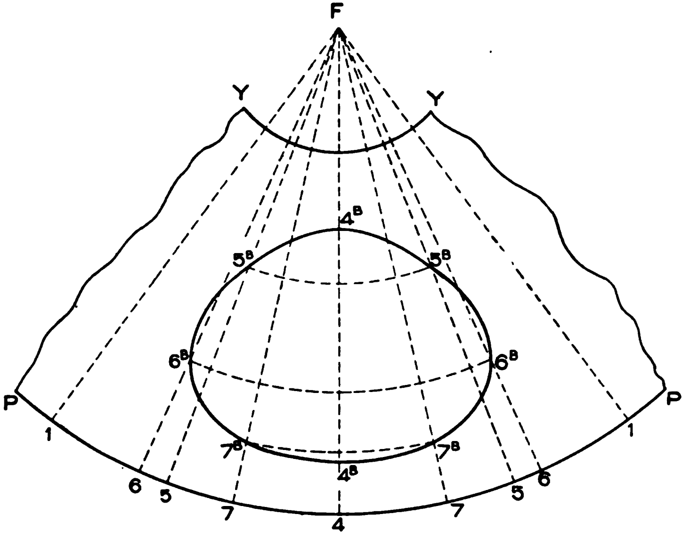
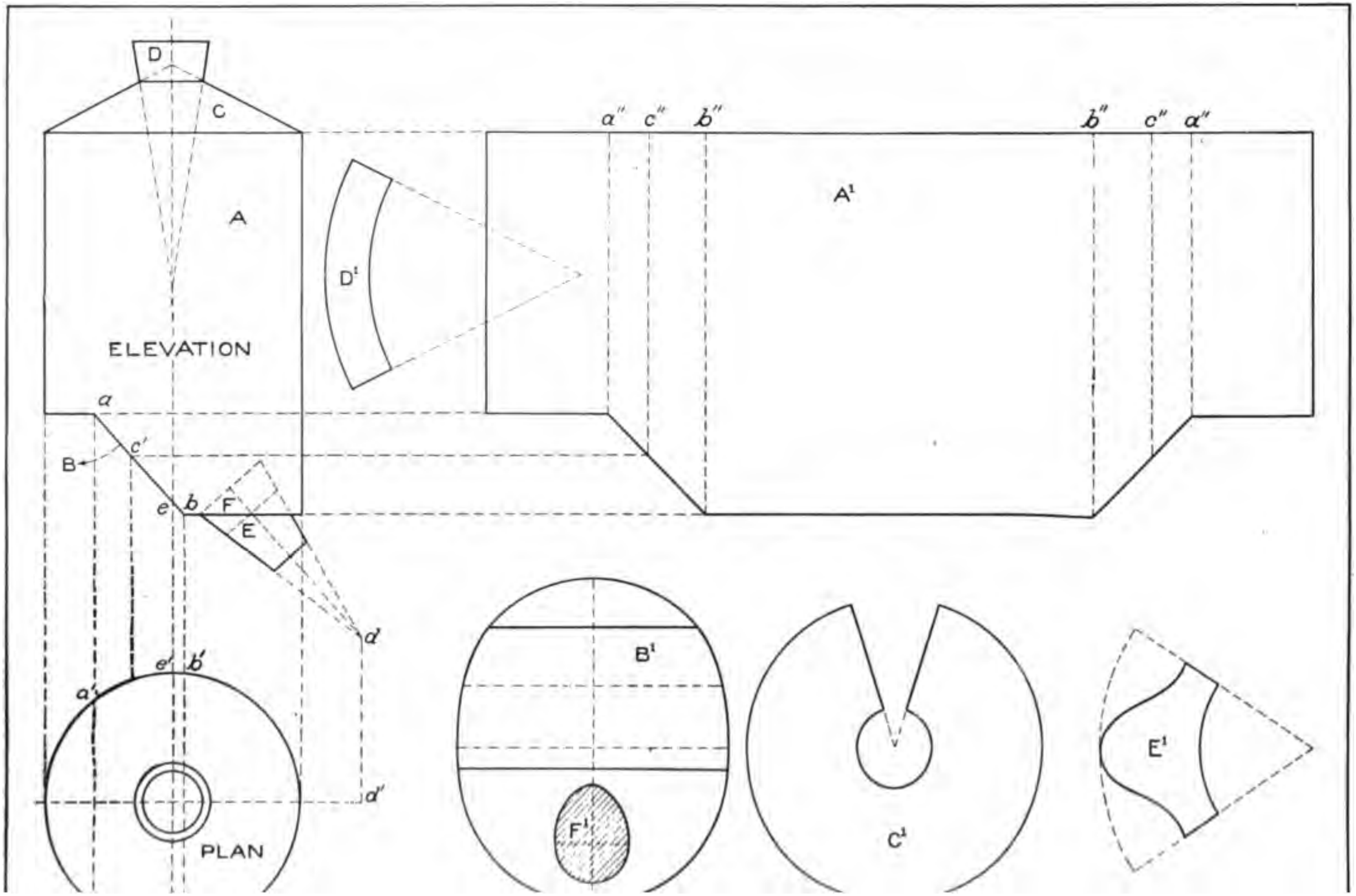

F
Y
Y
4^B
5^B
5^B
6^B
6^B
7^B
4^B
7^B
P
P
1
6
5
7
4
7
5
6
1

FIG. 2

PLATE IV

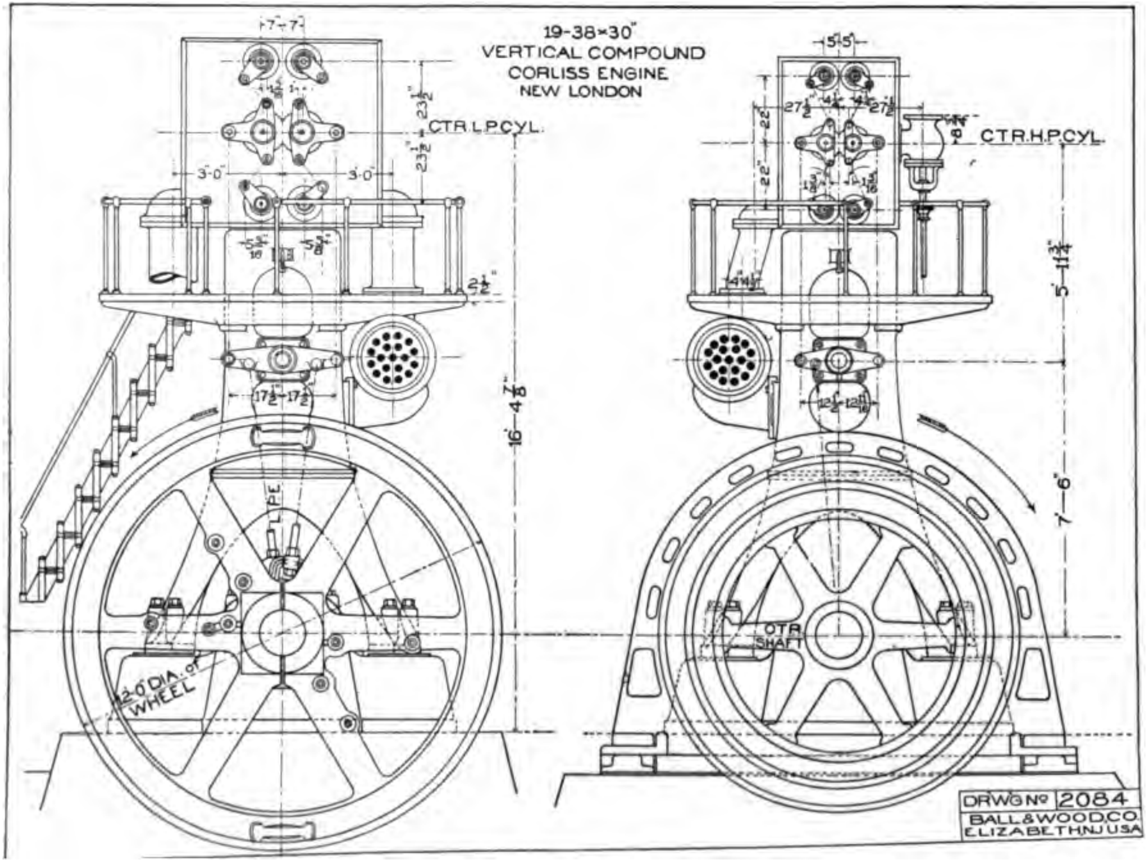


cone to admit the intersection of the smaller. We must now again refer to Plate II. From the intersections a, 5°, 6°, 7°, and o in elevation draw lines at right angles to the line of the axis, intersecting the side of the cone at 4^B, 5^B, 6^B, 7^B and 4^B.

Also in addition to the spaces 1, 2, 3 and 4 in the plan view, it will be necessary to obtain the points of intersection on the base line in plan, where the radial lines would intersect drawn from the apex F^1 through the points of intersections between the two cones. This is accomplished by drawing lines from F^1 through 5^x, 6^x and 7^x until they intersect the base line in plan at 5, 6 and 7. All these points form the basis with which to develop the pattern shown in Fig. 2 of Plate III, in which draw the vertical line F 4, and with F as a center and radii equal to FY, and F P in Plate II draw the arcs YY and PP in Fig. 2 of Plate III as shown. Now starting from the point 4 on the arc PP on either side, lay off the stretchout of 1, 6, 5, 7 and 4 in plan in Plate II as shown by similar numbers in Fig. 2 of Plate III. From the points 6, 5, 7 and 4 on either side draw radial lines to the apex F, which will be used to obtain the pattern for the opening. Now with F as center and radii equal to F 4^B, F 5^B, F 6^B, F 7^B and F 4^B in Plate II, describe arcs intersecting radial lines having similar numbers in Fig. 2 of Plate III as shown by intersections having similar numbers. A line traced through these points will be the required opening to be cut out of the pattern of the larger cone, one-half of which is shown by drawing radial lines from the points 1 and 1 to the apex F.

PLATE IV.

In drawing this plate, the same size paper and border lines should be used as for the preceding plates. The subject for this plate is an oil tank resting on inclined wooden racks. The problem involves patterns in parallel and radial-line developments. The drawing can be made to any convenient scale until the problems are understood and should be proven by paste-board models. It should be drawn to a convenient scale, placing the pattern to fill the sheet and make a neat appearance. The section, stretchout lines, construction lines, and developments should be numbered or lettered, so as to prove the thorough understanding of the problem, and then sent to the School for correction. The var-


19-38×30"
VERTICAL COMPOUND
CORLISS ENGINE
NEW LONDON
7"-7"
23½"
CTR.L.P.CYL.
3'-0"
3'-0"
5$\frac{3}{16}$"
5⅜"
2½"
17½"-17½"
16'-4⅞"
L.P.E.
12'-0" DIA. of WHEEL
5"-5"
27½"
4¼"
4¼"
27½"
22"
22"
CTR.H.P.CYL.
5'-11¾"
7'-6"
12½"-12$\frac{11}{16}$"
CTR. SHAFT
DRWG Nº 2084
BALL & WOOD CO.
ELIZABETH N.J. U.S.A.

MECHANICAL DRAWING.

The subject of mechanical drawing is of great interest and importance to all mechanics and engineers. Drawing is the method used to show graphically the small details of machinery; it is the language by which the designer speaks to the workman; it is the most graphical way to place ideas and calculations on record. Working drawings take the place of lengthy explanations, either written or verbal. A brief inspection of an accurate, well-executed drawing gives a better idea of a machine than a large amount of verbal description. The better and more clearly a drawing is made, the more intelligently the workman can comprehend the ideas of the designer. A thorough training in this important subject is necessary to the success of everyone engaged in mechanical work. The success of a draftsman depends to some extent upon the quality of his instruments and materials. Beginners frequently purchase a cheap grade of instruments. After they have become expert and have learned to take care of their instruments they discard them for those of better construction and finish. This plan has its advantages, but to do the best work, strong, well-made and finely finished instruments are necessary.

INSTRUMENTS AND MATERIALS.

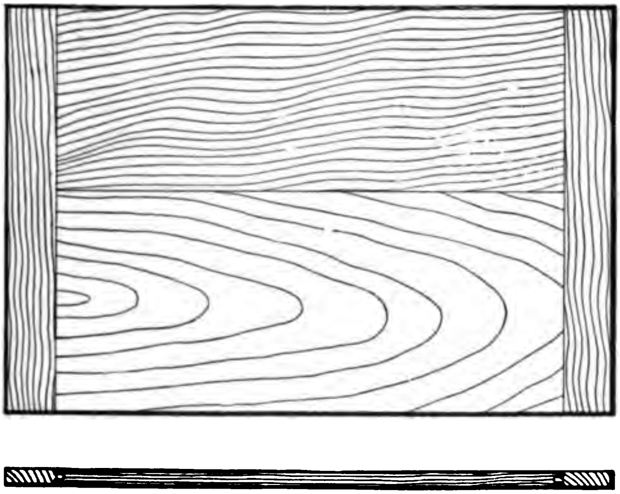
Drawing Paper. In selecting drawing paper, the first thing to be considered is the kind of paper most suitable for the proposed work. For shop drawings, a manilla paper is frequently used, on account of its toughness and strength, because the drawing is likely to be subjected to considerable hard usage. If a finished drawing is to be made, the best white drawing paper should be obtained, so that the drawing will not fade or become discolored with age. A good drawing paper should be strong, have uniform thickness and surface, should stretch evenly, and should neither repel nor absorb liquids. It should also allow considerable erasing without spoiling the surface, and it should lie smooth when stretched or when ink or colors are used. It is, of course, impossible to find all of these qualities in any one paper, as for instance great strength cannot be combined with fine surface.

In selecting a drawing paper the kind should be chosen which combines the greatest number of these qualities for the given work. Of the better class Whatman's are considered by far the best. This paper is made in three grades; the *hot pressed* has a smooth surface and is especially adapted for pencil and very fine line drawing, the *cold pressed* is rougher than the hot pressed, has a finely grained surface and is more suitable for water color drawing; the *rough* is used for tinting. The cold pressed does not take ink as well as the hot pressed, but erasures do not show as much on it, and it is better for general work. There is but little difference in the two sides of Whatman's paper, and either can be used. This paper comes in sheets of standard sizes as follows:—

Cap,	13 × 17	inches.	Elephant,	23 × 28	inches.
Demy,	15 × 20	"	Columbia,	23 × 34	"
Medium,	17 × 22	"	Atlas,	26 × 34	"
Royal,	19 × 24	"	Double Elephant,	27 × 40	"
Super-Royal,	19 × 27	"	Antiquarian,	31 × 53	"
Imperial,	22 × 30	"	Emperor,	48 × 68	"

The usual method of fastening paper to a drawing board is by means of thumb tacks or small one-ounce copper or iron tacks. In fastening the paper by this method first fasten the upper left hand corner and then the lower right pulling the paper taut. The other two corners are then fastened, and sufficient number of tacks are placed along the edges to make the paper lie smoothly. For very fine work the paper is usually stretched and glued to the board. To do this the edges of the paper are first turned up all the way round, the margin being at least one inch. The whole surface of the paper included between these turned up edges is then moistened by means of a sponge or soft cloth and paste or glue is spread on the turned up edges. After removing all the surplus water on the paper, the edges are pressed down on the board, commencing at one corner. During this process of laying down the edges, the paper should be stretched slightly by pulling the edges towards the edges of the drawing board. The drawing board is then placed horizontally and left to dry. After the paper has become dry it will be found to be as smooth and tight as a drum head. If, in stretching, the paper is stretched too much it is likely to split in drying. A slight stretch is sufficient.

Drawing Board. The size of the drawing board depends upon the size of paper. Many draftsmen, however, have several boards of various sizes, as they are very convenient. The drawing board is usually made of soft pine, which should be well seasoned and straight grained. The grain should run lengthwise of the board, and at the two ends there should be pieces about $1\frac{3}{4}$ or 2 inches wide fastened to the board by nails or screws. These end pieces should be perfectly straight for accuracy in using the T-square. Frequently the end pieces are fastened by a glued matched joint, nails and screws being also used. Two cleats on the bottom extending the whole width of the board, will reduce the tendency to warp, and make the board easier to move as they raise it from the table.



DRAWING BOARD.

Thumb Tacks. Thumb tacks are used for fastening the paper to the drawing board. They are usually made of steel either pressed into shape, as in the cheaper grades, or made with a head of German silver with the point screwed and riveted to it. They are made in various sizes and are very convenient as they can be easily removed from the board. For most work however, draftsmen use small one-ounce copper or iron tacks, as they can be forced flush with the drawing paper, thus offering no obstruction to the T-square. They also possess the advantage of cheapness.

Pencils. In pencilling a drawing the lines should be very fine and light. To obtain these light lines a hard lead pencil must be used. Lead pencils are graded according to their hardness, and are numbered by using the letter H. In general a lead pencil of 5H (or HHHHH) or 6H should be used. A softer pencil, 4H, is better for making letters, figures and points. A hard lead pencil should be sharpened as shown in Fig. 1. The wood is cut away so that about $\frac{1}{4}$ or $\frac{3}{8}$ inch of lead projects. The lead can then be sharpened to a chisel edge by rubbing it against a bit of sand paper or a fine file. It should be ground to a chisel edge and the corners slightly rounded. In making the straight lines the chisel edge should be used by placing it against the T-square or triangle, and because of the chisel edge the lead will remain sharp much longer than if sharpened to a point. This chisel edge enables the draftsman to draw a fine line exactly through a given point. If the drawing is not to be inked, but is made for tracing or for rough usage in the shop, a softer pencil, 3H or 4H, may be used, as the lines will then be somewhat thicker and heavier. The lead for compasses may also be sharpened to a point although some draftsmen prefer to use a chisel edge in the compasses as well as for the pencil.

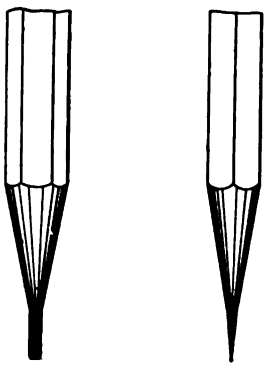


Fig. 1.

In using a very hard lead pencil, the chisel edge will make a deep depression in the paper if much pressure is put on the pencil. As this depression cannot be erased it is much better to press lightly on the pencil.

Erasers. In making drawings, but little erasing should be necessary. However, in case this is necessary, a soft rubber should be used. In erasing a line or letter, great care must be exercised or the surrounding work will also become erased. To prevent this, some draftsmen cut a slit about 3 inches long and $\frac{1}{8}$ to $\frac{1}{4}$ inch wide in a card as shown in Fig. 2. The card is then placed over the work and the line erased without erasing the rest of the drawing. An erasing shield of a form similar to that shown in Fig. 3 is very convenient, especially in erasing letters. It is made of thin sheet metal and is clean and durable.

For cleaning drawings, a sponge rubber may be used. Bread crumbs are also used for this purpose. To clean the drawing scatter *dry* bread crumbs over it and rub them on the surface with the hand.

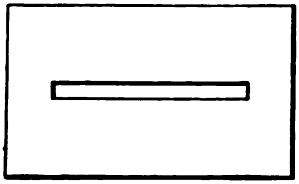


Fig. 2.

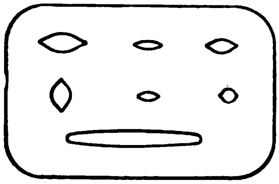


Fig. 3.

T-Square. The T-square consists of a thin straight edge called the blade, fastened to a head at right angles to it. It gets its name from the general shape. T-squares are made of various materials, wood being the most commonly used. Fig. 4 shows an ordinary form of T-square which is adapted to most work. In Fig. 5 is shown a T-square with edges made of ebony or mahogany, as these woods are much harder than pear wood or maple, which is generally used. The head is formed so as to fit against the left-hand edge of the drawing board, while the blade extends over the surface. It is desirable to have the blade of the T-square form a right angle with the head, so that the lines drawn with the T-square will be at right angles to the left-hand edge of the board. This, however, is not absolutely necessary, because the lines drawn with the T-square are always with reference to one edge of the

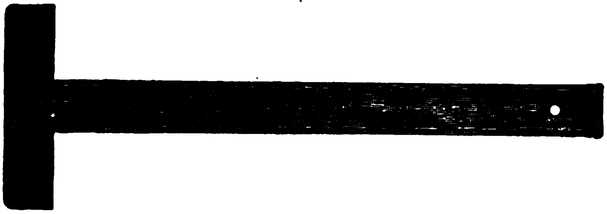


Fig. 4.

board only, and if this edge of the board is straight, the lines drawn with the T-square will be parallel to each other. The T-square should never be used except with the left-hand edge of the board, as it is almost impossible to find a drawing broad with the edges parallel or at right angles to each other.

The T-square with an adjustable head is frequently very convenient, as it is sometimes necessary to draw lines parallel to each other which are not at right angles to the left-hand edge of the board. This form of T-square is similar to the ordinary T-square already described, but the head is swiveled so that it may be clamped at any desired angle. The ordinary T-square as shown in Figs. 4 and 5 is, however, adapted to almost any class of drawing.

Fig. 5.

Fig. 6 shows the method of drawing parallel horizontal lines with the T-square. With the head of the T-square in contact with the left-hand edge of the board, the lines may be drawn by moving the T-square to the desired position. In using the T-square the upper edge should always be used for drawing as the two edges may not be exactly parallel and straight, and also it is more convenient to use this edge with the triangles. If it is necessary to use a straight edge for trimming drawings or cutting the paper from the board, the lower edge of the T-square should be used so that the upper edge may not be marred.

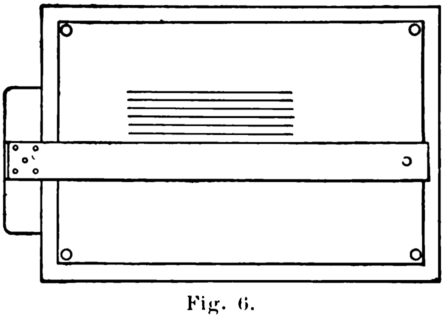


Fig. 6.

For accurate work it is absolutely necessary that the working edge of the T-square should be exactly straight. To test the straightness of the edge of the T-square, two T-squares may be placed together as shown in Fig. 7. This figure shows plainly that the edge of one of the T-squares is crooked. This fact, however, does not prove that either one is straight, and for this determination a third blade must be used and tried with the two given T-squares successively.

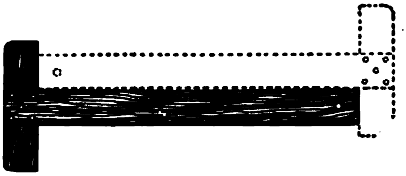
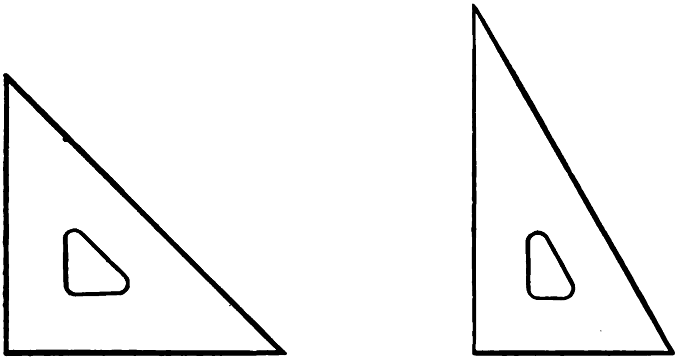


Fig. 7.

Triangles. Triangles are made of various substances such as wood, rubber, celluloid and steel. Wooden triangles are cheap but are likely to warp and get out of shape. The rubber triangles are frequently used, and are in general satisfactory. The transparent celluloid triangle is, however, extensively used on account of its transparency, which enables the draftsmen to see the work already done even when covered with the triangle. In using a rubber or celluloid triangle take care that it lies perfectly flat or is hung up when not in use; when allowed to lie on the drawing board with a pencil or an eraser under one corner it will become warped in a short time, especially if the room is hot or the sun happens to strike the triangle.



TRIANGLES.

Triangles are made in various sizes, and many draftsmen have several constantly on hand. A triangle from 6 to 8 inches on a side will be found convenient for most work, although there are many cases where a small triangle measuring about 4 inches on a side will be found useful. Two triangles are necessary for every draftsman, one having two angles of 45 degrees each and one a right angle; and the other having one angle of 60 degrees, one of 30 degrees and one of 90 degrees.

The value of the triangle depends upon the accuracy of the angles and the straightness of the edges. To test the accuracy of the right angle of a triangle, place the triangle with the lower edge resting on the edge of the T-square, as shown in Fig. 8. Now draw the line C D, which should be perpendicular to the edge of the T-square. The same triangle should then be placed in the position shown at B. If the right angle of the triangle is exactly 90 degrees the left-hand edge of the triangle should exactly coincide with the line C D.

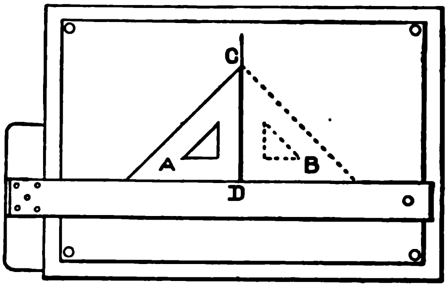


Fig. 8.

To test the accuracy of the 45-degree triangles, first test the right angle then place the triangle with the lower edge resting on the working edge of the T-square, and draw the line E F as shown in Fig. 9. Now without moving the T-square place the triangle so that the other 45-degree angle is in the position occupied by the first. If the two 45-degree angles coincide they are accurate.

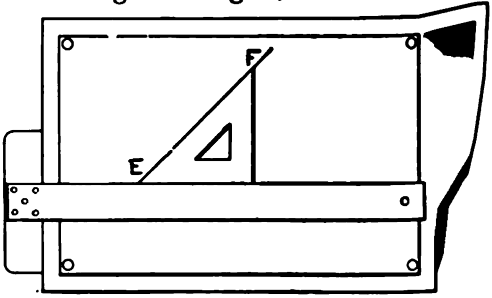
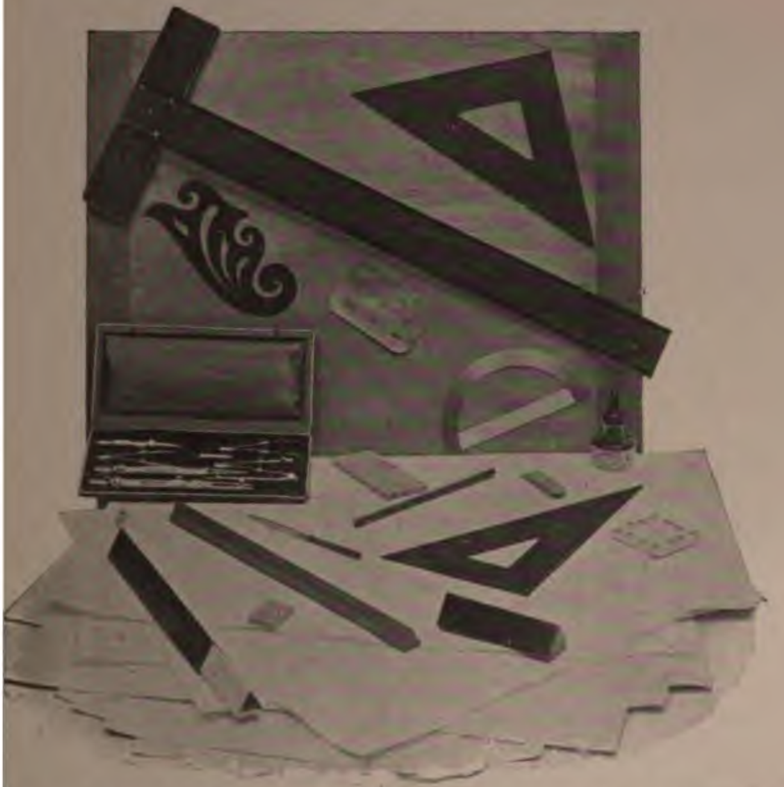


Fig. 9.

Triangles are very convenient in drawing lines at right angles to the T-square. The method of doing this is shown in Fig. 10. Triangles are also used in drawing lines at an angle with the horizontal, by placing them on the board as shown in Fig. 11. Suppose the line E F (Fig. 12) is drawn at any angle, and we wish to draw a line through the point P parallel to it.



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First place one of the triangles as shown at A, having one edge coinciding with the given line. Now take the other triangle and place one of its edges in contact with the bottom edge of triangle A. Holding the triangle B firmly with the left hand the triangle A may be slipped along to the right or to the left until the edge of the triangle reaches the point P. The line M N may then be drawn along the edge of the triangle passing through the point P. In place of the triangle B any straight edge such as a T-square may be used.

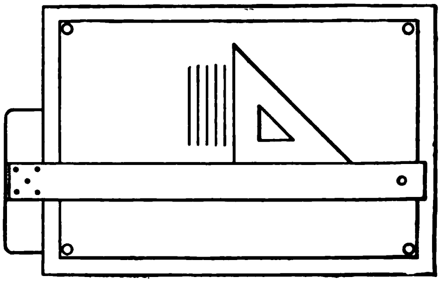


Fig. 10.

A line can be drawn perpendicular to another by means of the triangles as follows. Let E F (Fig. 13) be the given line, and suppose we wish to draw a line perpendicular to E F through the point D. Place the longest side of one of the triangles so that it coincides with the line E F, as the triangle is shown in position at A. Place the other triangle (or any straight edge) in the position of the triangle as shown at B, one edge resting against the edge of the triangle A. Then holding B with the left hand, place the triangle A in the position shown at C, so that the longest side passes through the point D. A line can then be drawn through the point D perpendicular to E F.

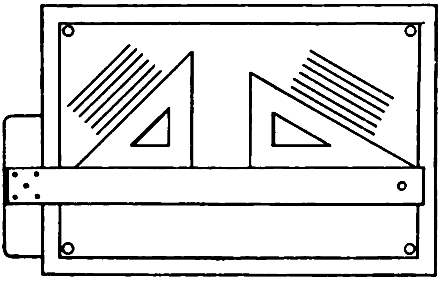


Fig. 11.

In previous figures we have seen how lines may be drawn making angles of 30, 45, 60 and 90 degrees with the horizontal. If it is desired to draw lines forming angles of 15 and 75 degrees the triangles may be placed as shown in Fig. 14.

In using the triangles and T-square almost any line may be drawn. Suppose we wish to draw a rectangle having one side horizontal. First place the T-square as shown in Fig. 15. By moving the T-square up or down, the sides A B and D C may be drawn, because they are horizontal and parallel. Now place one of the triangles resting on the T-square as shown at E, and having the left-hand edge passing through the point D. The vertical line D A may be drawn, and by sliding the triangle along the edge of the T-square to the position F the line B C may be drawn by using the same edge. These positions are shown dotted in Fig. 15.

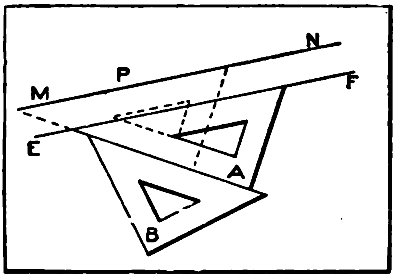


Fig. 12.

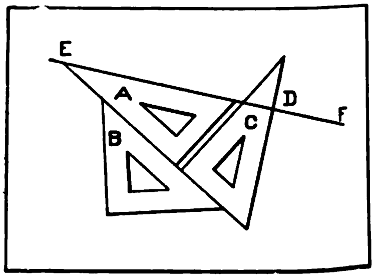


Fig. 13.

If the rectangle is to be placed in some other position on the drawing board, as shown in Fig. 16, place the 45-degree triangle F so that one edge is parallel to or coincides with the side D C. Now holding the triangle F in position place the triangle H so that its upper edge coincides with the lower edge of the triangle F. By holding H in position and sliding the triangle F along its upper edge, the sides A B and D C may be drawn. To draw the sides A D and B C the triangle should be used as shown at E.

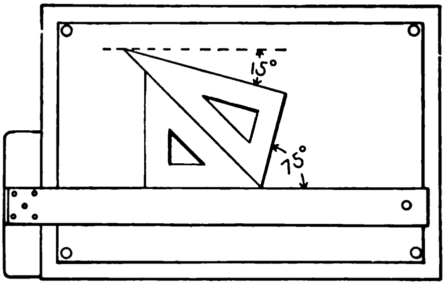


Fig. 14.

Compasses. Compasses are used for drawing circles and arcs of circles. They are made of various materials and in various sizes. The cheaper class of instruments are made of brass, but they are unsatisfactory on account of the odor and the tendency to tarnish. The best material is German silver. It does not soil readily, it has no odor, and is easy to keep clean. Aluminum instruments possess the advantage of lightness, but on account of the soft metal they do not wear well.

The compasses are made in the form shown in Figs. 17 and 18. Pencil and pen points are provided, as shown in Fig. 17. Either pen or pencil may be inserted in one leg by means of a shank and socket. The other leg is fitted with a needle point which is placed at the center of the circle. In most instruments the needle point is separate, and is made of a piece of round steel wire having a square shoulder at one or both ends. Below this shoulder the needle point projects. The needle is made in this form so that the hole in the paper may be very minute.

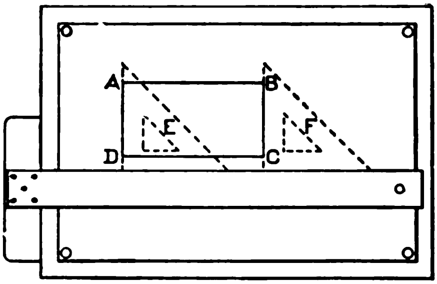


Fig. 15.

In some instruments lock nuts are used to hold the joint firmly in position. These lock nuts are thin discs of steel, with notches for using a wrench or forked key. Fig. 19 shows the detail of the joint of high grade instruments. Both legs are alike at the joint, and two pivoted screws are inserted in the yoke. This permits ample movement of the legs, and at the same time gives the proper stiffness. The flat surface of one of the legs is faced with steel, the other being of German silver, in order that the rubbing parts may be of different metals. Small set screws are used to prevent the pivoted screws from turning in the yoke. The contact surfaces of this joint are made circular to exclude dust and dirt and to prevent rusting of the steel face.

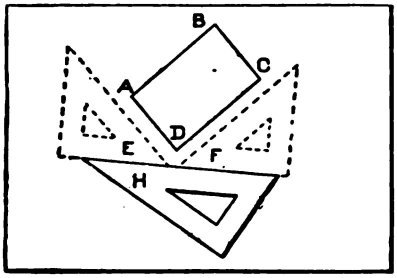


Fig. 16.

Figs. 20, 21, and 22 show the detail of the socket; in some instruments the shank and socket are pentagonal, as shown in Fig. 20. The shank enters the socket loosely, and is held in place by means of the screw. Unless used very carefully this arrangement is not durable because the sharp corners soon wear, and the pressure on the set screw is not sufficient to hold the shank firmly in place.

In Fig. 21 is shown another form of shank. This is round, having a flat top. A set screw is also used to hold this in position. A still better form of socket is shown in Fig. 22; the hole is made tapered and is circrlar. The shank fits accurately, and is held in perfect alignment by a small steel key. The clamping screw is placed upon the side, and keeps the two portions of the split socket together.

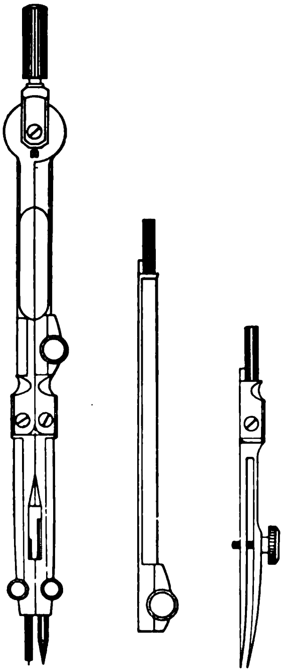


Fig. 17.

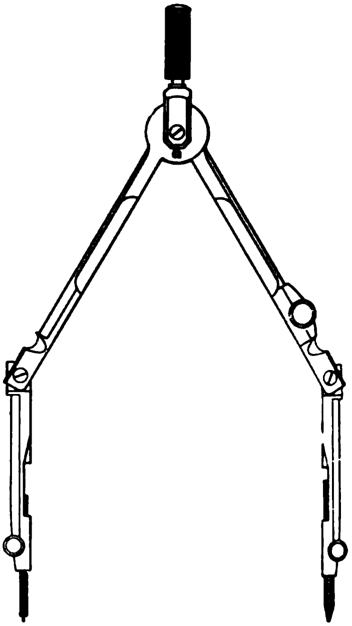


Fig. 18.

Figs. 17 and 18 show that both legs of the compasses are jointed in order that the lower part of the legs may be perpendicular to the paper while drawing circles. In this way the needle point makes but a small hole in the paper, and both nibs of the pen will press equally on the paper. In pencilling circles it is not as necessary that the pencil should be kept vertical; it is a good plan, however, to learn to use them in this way both in pencilling and inking. The compasses should be held loosely between the thumb and forefinger. If the needle point is sharp, as it should be, only a slight pressure will be required to keep it in place. While drawing the circle, incline the compasses slightly in the direction of revolution and press lightly on the pencil or pen.

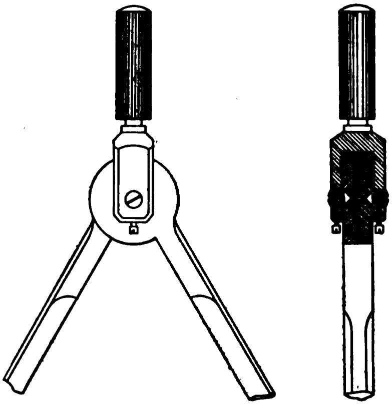


Fig. 19.

In removing the pencil or pen, it should be pulled out straight. If bent from side to side the socket will become enlarged and the shank worn; this will render the instrument inaccurate. For drawing large circles the lengthening bar shown in Fig. 17 should be used. When using the lengthening bar the needle point should be steadied with one hand and the circle described with the other.

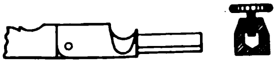


Fig. 20.

Fig. 21.

Dividers. Dividers, shown in Fig. 23, are made similar to the compasses. They are used for laying off distances on the drawing, either from scales or from other parts of the drawing. They may also be used for dividing a line into equal parts. When dividing a line into equal parts the dividers should be turned in the opposite direction each time, so that the moving point passes alternately to the right and to the left. The instrument can then be operated readily with one hand. The points of the dividers should be very sharp so that the holes made in the paper will be small. If large holes are made in the paper, and the distances between

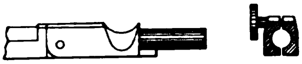


Fig. 22.

the points are not exact, accurate spacing cannot be done Sometimes the compasses are furnished with steel divider points in addition to the pen and pencil points. The compasses may then be used either as dividers or as compasses. Many draftsmen use a *needle point* in place of dividers for making measurements from a scale. The eye end of a needle is first broken off and the needle then forced into a small handle made of a round piece of soft pine. This instrument is very convenient for indicating the intersection of lines and marking off distances.

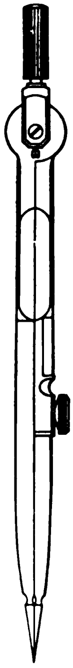


Fig. 23.

Bow Pen and Bow Pencil. Ordinary large compasses are too heavy to use in making small circles, fillets, etc. The leverage of the long leg is so great that it is very difficult to draw small circles accurately. For this reason the bow compasses shown in Figs. 24 and 25 should be used on all arcs and circles having a radius of less than three-quarters inch. The bow compasses are also convenient for duplicating small circles such as those which represent boiler tubes, bolt holes, etc., since there is no tendency to slip.

The needle point must be adjusted to the same length as the pen or pencil point if very small circles are to be drawn. The adjustment for altering the radius of the circle can be made by turning the nut. If the change in radius is considerable the points should be pressed together to remove the pressure from the nut which can then be turned in either direction with but little wear on the threads.

Fig. 26 shows another bow instrument which is frequently used in small work in place of the dividers. It has the advantage of retaining the adjustment.

Drawing Pen. For drawing straight lines and curves that are not arcs of circles, the line pen (sometimes called the ruling pen) is used. It consists of two blades of steel fastened to a handle as shown in Fig. 27. The distance between the pen points can be adjusted by the thumb screw, thus regulating the width of line to be drawn. The blades are given a slight curvature so that there will be a cavity for ink when the points are close together.

The pen may be filled by means of a common steel pen or with the quill which is provided with some liquid inks. The pen should not be dipped in the ink because it will then be necessary to wipe the outside of the blades before use. The ink should fill the pen to a height of about $\frac{1}{4}$ or $\frac{3}{8}$ inch; if too much ink is placed in the pen it is likely to drop out and spoil the drawing. Upon finishing the work the pen should be carefully wiped with chamois or a soft cloth, because most liquid inks corrode the steel.

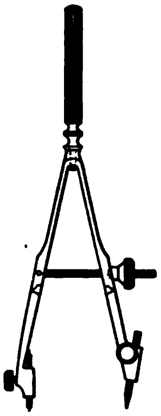


Fig. 24.

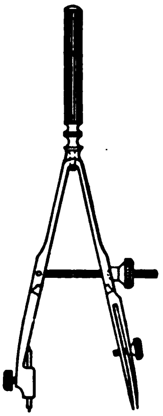


Fig. 25.

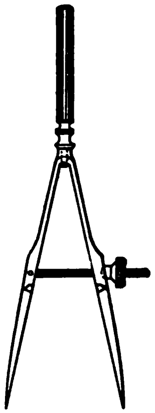


Fig. 26.

In using the pen, care should be taken that both blades bear equally on the paper. If the points do not bear equally the line will be ragged. If both points touch, and the pen is in good condition the line will be smooth. The pen is usually inclined slightly in the direction in which the line is drawn. The pen should *touch* the triangle or T-square which serve as guides, but it should not be pressed against them because the lines will then be uneven. The points of the pen should be close to the edge of the triangle or T-square, but should not touch it.

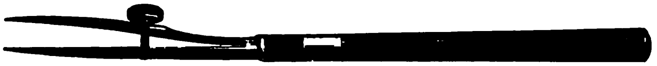


Fig. 27.

To Sharpen the Drawing Pen. After the pen has been used for some time the points become worn, and it is impossible to make smooth lines. This is especially true if rough paper is used. The pen can be put in proper condition by sharpening it. To do this take a small, flat, close-grained oil-stone. The blades should first be screwed together, and the points of the pen can be given the proper shape by drawing the pen back and forth over the stone changing the inclination so that the shape of the ends will be parabolic. This process dulls the points but gives them the proper shape, and makes them of the same length.

To sharpen the pen, separate the points slightly and rub one of them on the oil-stone. While doing this keep the pen at an angle of from 10 to 15 degrees with the face of the stone, and give it a slight twisting movement. This part of the operation requires great care as the shape of the ends must not be altered. After the pen point has become fairly sharp the other point should be ground in the same manner. All the grinding should be done on the *outside* of the blades. The burr should be removed from the inside of the blades by using a piece of leather or a piece of pine wood.

Ink should now be placed between the blades and the pen tried. The pen should make a smooth line whether fine or heavy, but if it does not the grinding must be continued and the pen tried frequently.

Ink. India ink is always used for drawing as it makes a permanent black line. It may be purchased in solid stick form or as a liquid. The liquid form is very convenient as much time is saved, and all the lines will be of the same color; the acid in the ink, however, corrodes steel and makes it necessary to keep the pen perfectly clean.

Some draftsmen prefer to use the India ink which comes in stick form. To prepare it for use, a little water should be placed in a saucer and one end of the stick placed in it. The ink is ground by giving it a twisting movement. When the water has become black and slightly thickened, it should be tried. A heavy line should be made on a sheet of paper and allowed to dry. If the line has a grayish appearance, more grinding is necessary. After the ink is thick enough to make a good black line, the grinding should cease, because very thick ink will not flow freely from the pen. If, however, the ink has become too thick, it may be diluted with water. After using, the stick should be wiped dry to prevent crumbling. It is well to grind the ink in small quantities as it does not dissolve readily if it has once become dry. If the ink is kept covered it will keep for two or three days.

Scales. Scales are used for obtaining the various measurements on drawings. They are made in several forms, the most convenient being the flat with beveled edges and the triangular. The scale is usually a little over 12 inches long and is graduated for a distance of 12 inches. The triangular scale shown in Fig. 28 has six surfaces for graduations, thus allowing many graduations on the same scale.

The graduations on the scales are arranged so that the drawings may be made in any proportion to the actual size. For mechanical work, the common divisions are multiples of two.

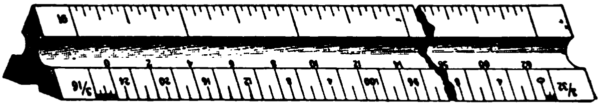


Fig. 28.

Thus we make drawings full size, half size, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$, etc. If a drawing is $\frac{1}{4}$ size, 3 inches equals 1 foot, hence 3 inches is divided into 12 equal parts and each division represents one inch. If the smallest division on a scale represents $\frac{1}{16}$ inch, the scale is said to read to $\frac{1}{16}$ inch.

Scales are often divided into $\frac{1}{10}$, $\frac{1}{20}$, $\frac{1}{30}$, $\frac{1}{40}$, etc., for architects, civil engineers, and for measuring on indicator cards.

The scale should never be used for drawing lines in place of triangles or T-square.

Protractor. The protractor is an instrument used for laying off and measuring angles. It is made of steel, brass, horn and paper. If made of metal the central portion is cut out as shown in Fig. 29, so that the draftsman can see the drawing. The outer edge is divided into degrees and tenths of degrees. Sometimes the graduations are very fine. In using a protractor a very sharp hard pencil should be used so that the lines will be fine and accurate.

The protractor should be placed so that the given line (produced if necessary) coincides with the two O marks. The center of the circle being placed at the point through which the desired line is to be drawn. The division can then be marked with the pencil point or needle point.

Irregular Curve. One of the conveniences of a draftsman's outfit is the French or irregular curve. It is made of wood, hard rubber or celluloid, the last named material being the best. It is made in various shapes, two of the most common being shown in Fig. 30. This instrument is used for drawing curves other than arcs of circles, and both pencil and line pen can be used.

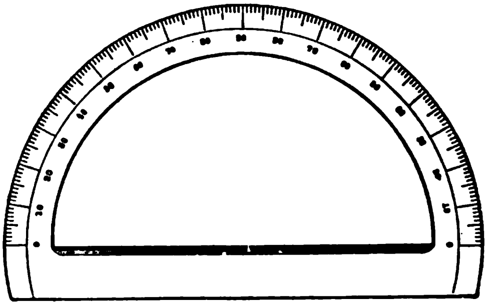


Fig. 29.

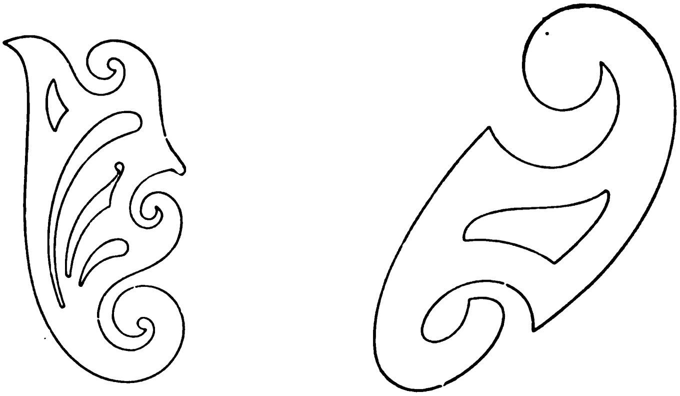


Fig. 30.

To draw the curve, a series of points is first located and then the curve drawn passing through them by using the part of the irregular curve that passes through several of them. The curve is shifted for this work from one position to another. It frequently facilitates the work and improves its appearance to draw a free hand pencil curve through the points and then use the irregular curve, taking care that it always fits at least *three* points.

In inking the curve, the blades of the pen must be kept tangent to the curve, thus necessitating a continual change of direction.*

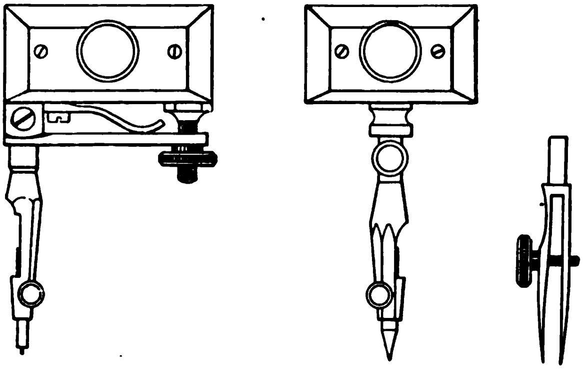


Fig. 31.

Beam Compasses. The ordinary compasses are not large enough to draw circles having a diameter greater than about 8 or 10 inches. A convenient instrument for larger circles is found in the beam compasses shown in Fig. 31. The two parts called channels carrying the pen or pencil and the needle point are clamped to a wooden beam; the distance between them being equal to the radius of the circle. Accurate adjustment is obtained by means of a thumb nut underneath one of the channel pieces.

PLATES.

Plates I, II and III are provided to give practice in the use of the drawing instruments. Drawing paper at least 11 inches by 15 inches should be used to allow border lines 10 inches by 14 inches. First, draw carefully in pencil and then ink in. Especial care should be taken as to quality and width of line, intersections, and the joining of curved and straight lines.

These are followed by examples for lettering. Plate IV should be drawn first in pencil and then in ink.

PLATE I

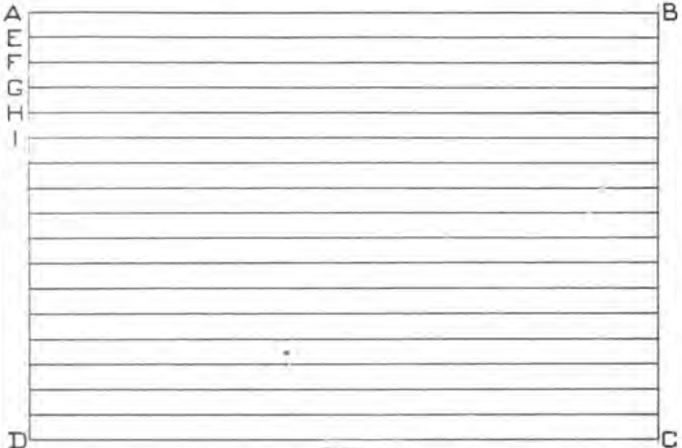


FIG. 1

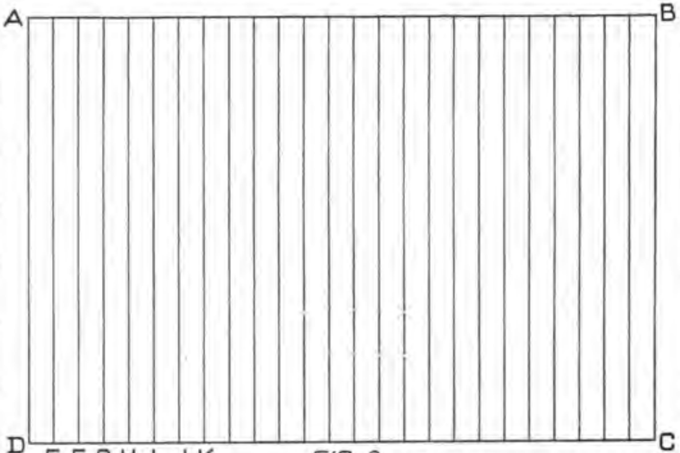
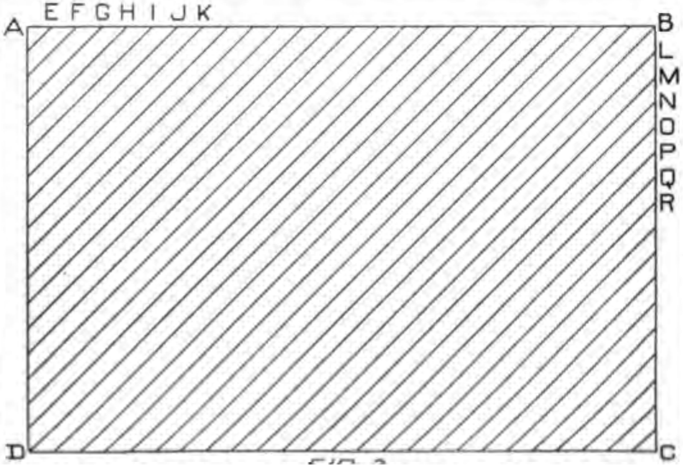
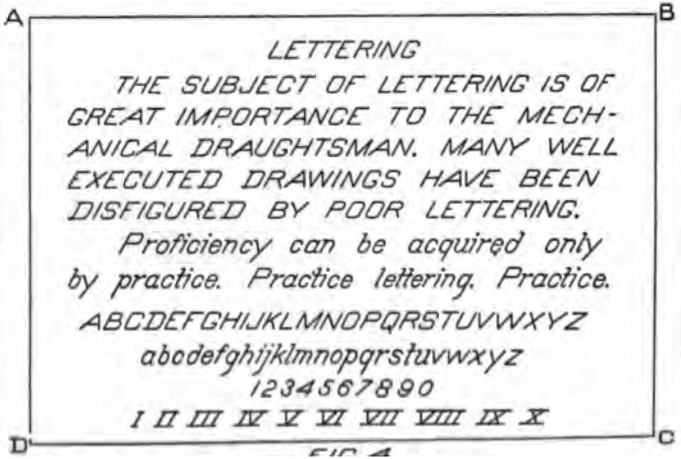


FIG. 2





LETTERING

THE SUBJECT OF LETTERING IS OF GREAT IMPORTANCE TO THE MECHANICAL DRAUGHTSMAN. MANY WELL EXECUTED DRAWINGS HAVE BEEN DISFIGURED BY POOR LETTERING.

Proficiency can be acquired only by practice. Practice lettering. Practice.

ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefghijklmnopqrstuvwxyz

1234567890

I II III IV V VI VII VIII IX X

PLATE —

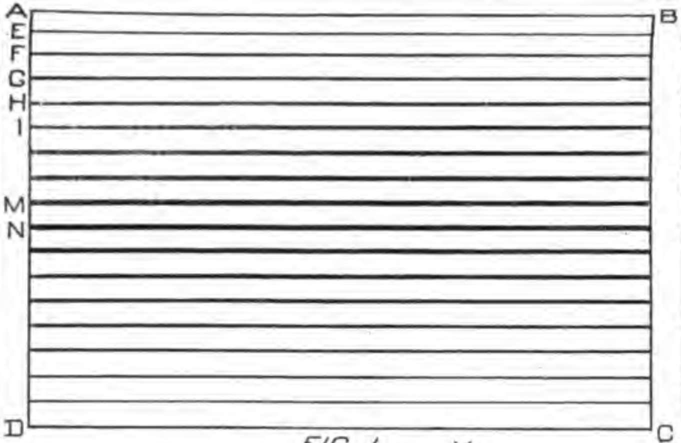


FIG. 1

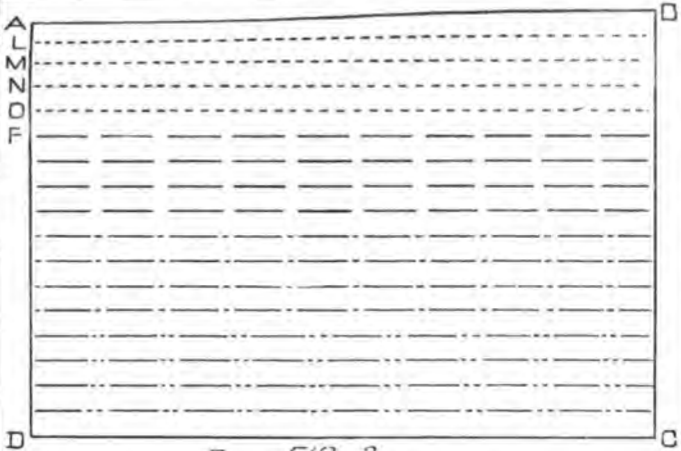


FIG. 2

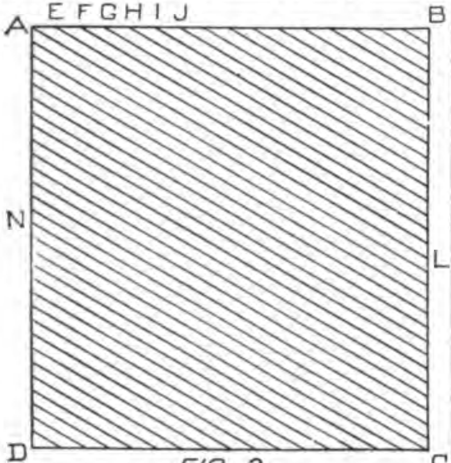


FIG. 3

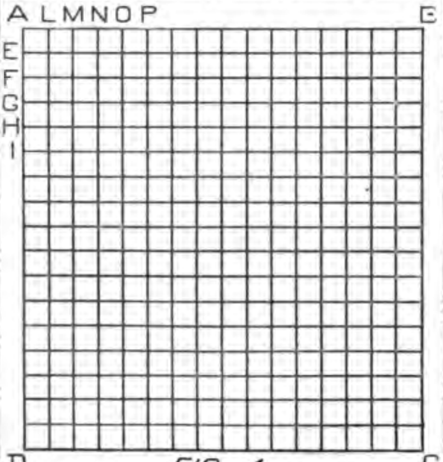


FIG. 4

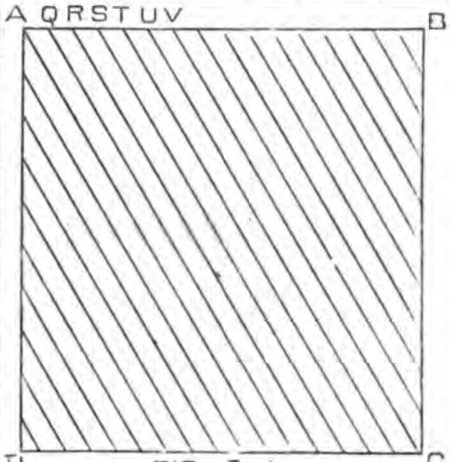


FIG. 5 L

JANUARY 9, 1901. HERBERT CHANDLER CHICAGO, ILL.

PLATE III

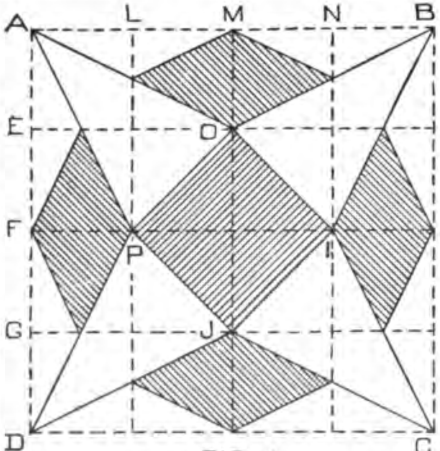


FIG. 1

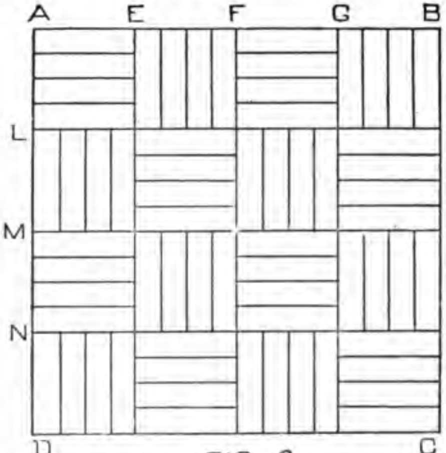


FIG. 2

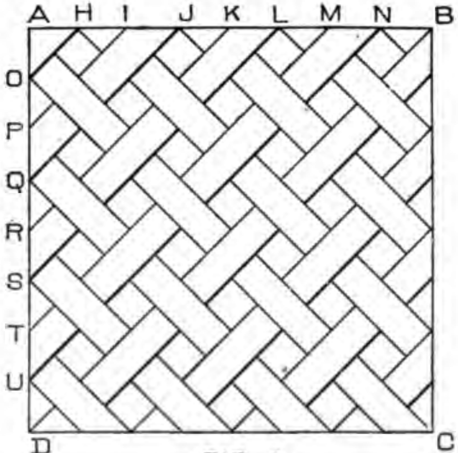


FIG. 3

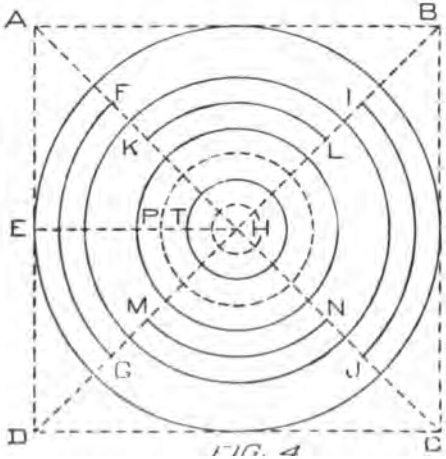


FIG. 4

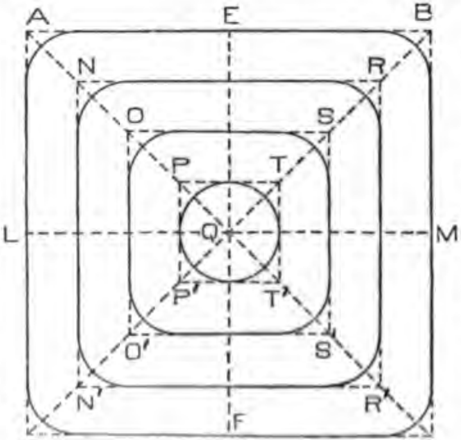


FIG. 5

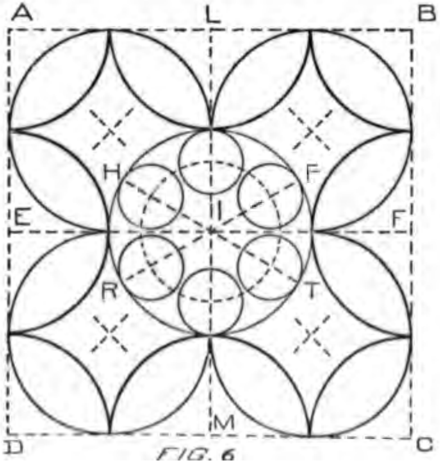


FIG. 6

COURSE

IN

MECHANICAL DRAWING

MACHINE DRAWINGS

AND

PROJECTIONS

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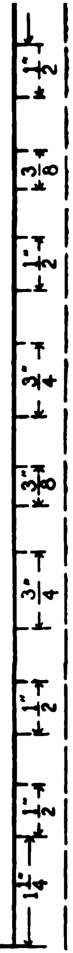

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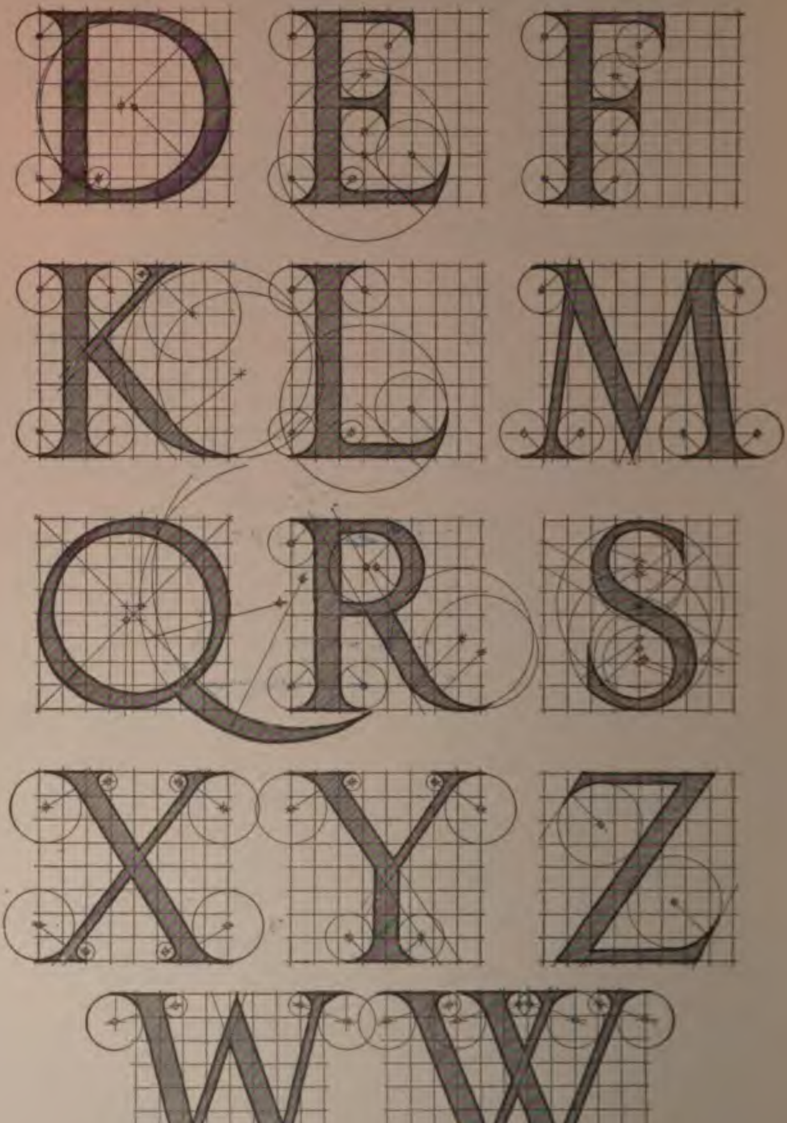

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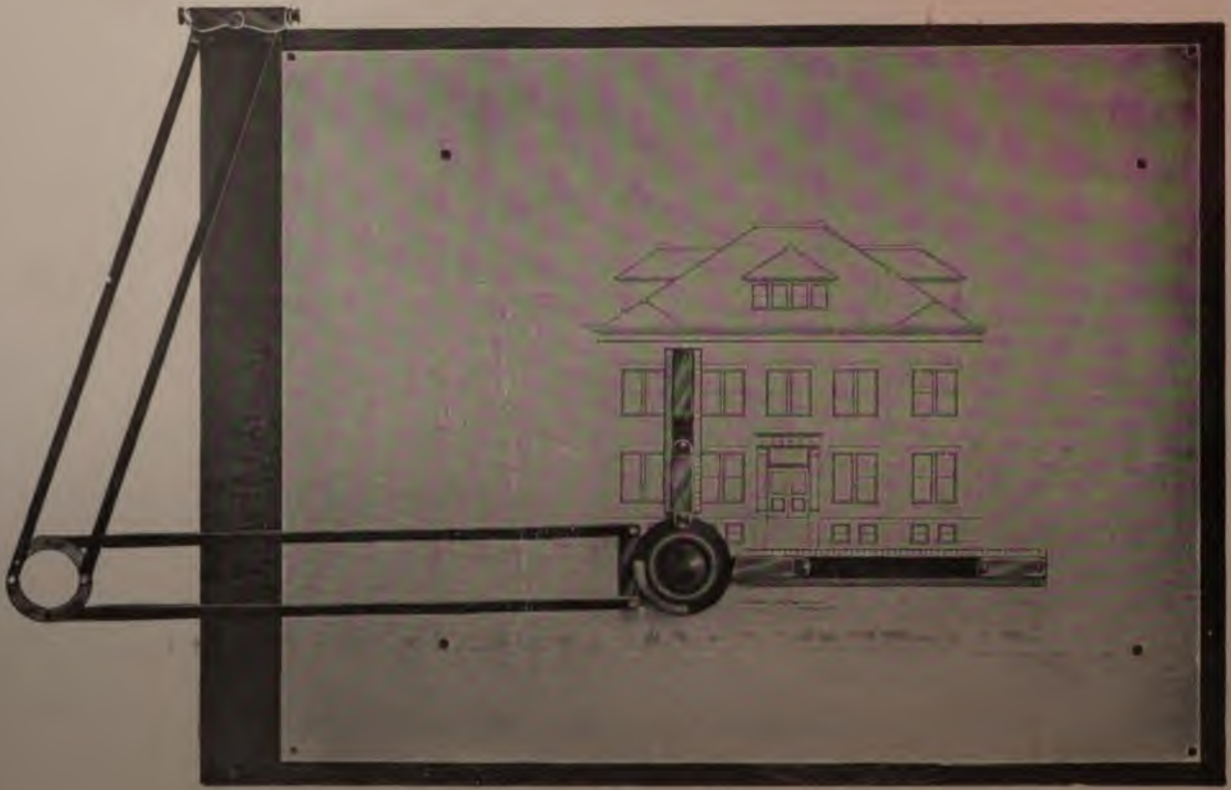


THE UNIVERSAL DRAFTING MACHINE.

MECHANICAL DRAWING.

PART II.

PROJECTIONS.

Orthographic Projection is the art of representing an object upon two planes, at right angles to each other, by lines drawn from all points on the edges or contour perpendicular to these planes. The intersections of the perpendiculars with the planes give figures which are called projections of the object.

The two planes are called *planes of projection*, or *coördinate planes*, one being vertical and the other horizontal, as shown in Fig. 1. These planes are sometimes designated V and H respectively. The intersection of V and H is known as the ground line, or G L. If a in Fig. 1 is a point in space, and a perpendicular is drawn to the vertical plane, the point a^v will be the projection of the point on the vertical plane, and in a similar way a^h will be the projection of a on the horizontal plane. The line B has its vertical projection at B^v, and its horizontal projection at B^h. Instead of *horizontal* projection and *vertical* projection, the terms **plan** and **elevation** are commonly used. It will be seen from the figure that the plan of a point or line is directly underneath on the H plane, and the elevation directly behind on the V plane.

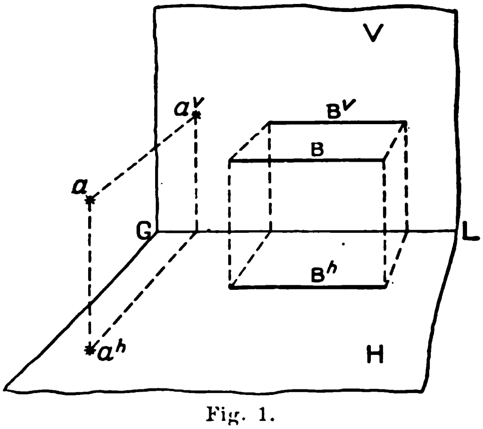


Fig. 1.

Suppose in Fig. 2 a cube one inch on a side be placed with the top horizontal and the front face parallel to the vertical plane. Then the plan will be a one-inch square, and the elevation also a one-inch square. In general the plan is a representation of the top of the object, and the elevation a view of the *front*. The plan then is a top view, and the elevation a front view. Since the plan is directly below the object, and the elevation directly behind, it follows that in actual drawing the plan must be vertically below the elevation, point for point. This is one of the fundamental principles of projection, and should be thoroughly understood.

The projection of a point can never be anything but a point. By referring to Fig. 1 it is clear that the height of *a* above the horizontal plane is equal to the distance of a^v above the ground line, and the distance of *a* in front of the vertical plane is equal to the distance of a^h in front of the ground line. Applying this principle to Fig. 3, the point represented by a^v and a^h must be a point $\frac{3}{4}$ inch above H and 1 inch in front of V.

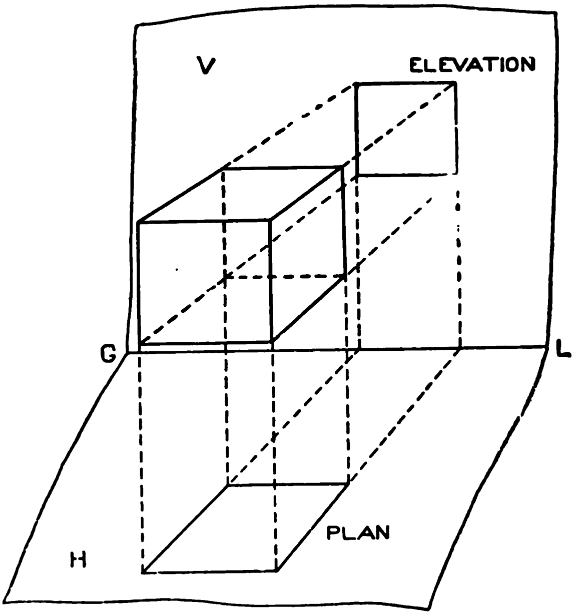


Fig. 2.

All points on an object at the same height must appear in elevation at the same distance above the ground line. If numbers 1, 2, 3 and 4 on the plan indicate the top corners of the cube, then these four points, being at the same height, must be shown in elevation at the same height and at the top, $\overset{4}{1}$ and $\overset{3}{2}$. The top of the cube, 1, 2, 3, 4, is shown in elevation as the straight line

$^{4}_{1}$ — $^{3}_{2}$. This illustrates the fact that *if a surface is perpendicular to either plane of projection, its projection on that plane is simply a line; a straight line if the surface is plane, a curved line if the surface is curved.* From the same figure it is seen that the top edge of the cube, 1 4, has for its projection on the vertical plane

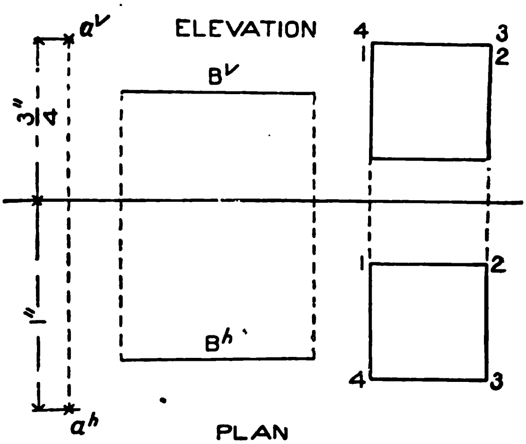


Fig. 3.

the point $^{4}_{1}$, the principle of which is stated in this way: If a straight line is perpendicular to either V or H, its projection on that plane is a point, and on the other plane is a line equal in length to the line itself, and perpendicular to the ground line.

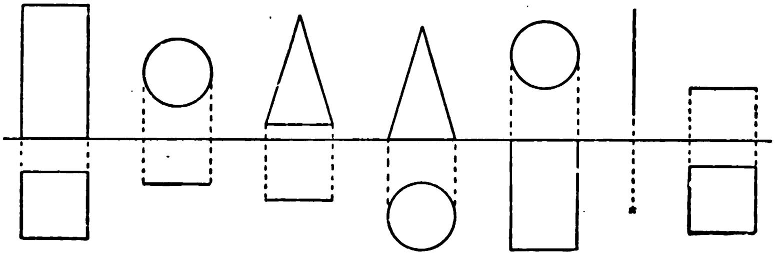


Fig. 4.

Fig. 4 is given as an exercise to help to show clearly the idea of plan and elevation. The student should answer the following question for himself: What does each of these projections represent?

Suppose in Fig. 5, that it is desired to construct the projections of a prism $1\frac{1}{2}$ in. square, and 2 in. long, standing on one end on the horizontal plane, two of its faces being parallel to the vertical plane. In the first place, as the top end of the prism is a square, the top view or plan will be a square of the same size, that is, $1\frac{1}{2}$ in. Then since the prism is placed parallel to and in front of the vertical plane the plan, $1\frac{1}{2}$ in. square, will have two edges parallel to the ground line. As the front face of the prism is parallel to the vertical plane its projection on V will be a rectangle, equal in length and width to the length and width respectively of the prism, and as the prism stands with its base on H, the elevation, showing height above H, must have its base on the ground line. Observe carefully that points in elevation are vertically over corresponding points in plan.

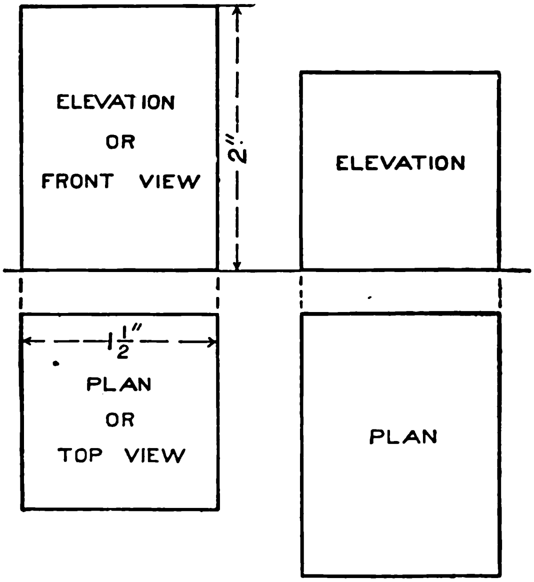


Fig. 5.

The second drawing in Fig. 5 represents a prism of the same size lying on one side on the horizontal plane, and with the ends parallel to V.

The principles which have been used thus far may be stated as follows, —

1. If a line or point is on either plane, its other projection must be in the ground line.

2. Height above H is shown in elevation as height above the ground line, and distance in front of the vertical plane is shown in plan as distance from the ground line.

3. If a line is parallel to either plane, its actual length is shown on that plane, and its other projection is parallel to the ground line. A line oblique to either plane has its projection on that plane shorter than the line itself, and its other projection oblique to the ground line. No projection can be longer than the line itself.

4. A plane surface if parallel to either plane, is shown on that plane in its true size and shape; if oblique it is shown smaller than the true size, and if perpendicular it is shown as a straight line. Lines parallel in space must have their V projections parallel to each other and also their H projections.

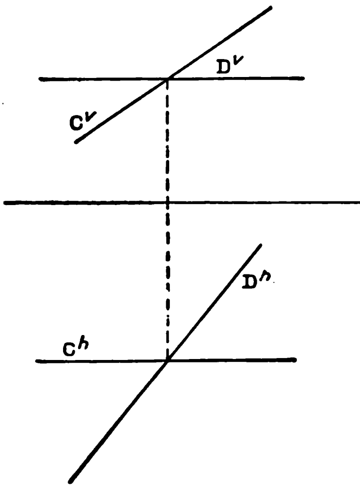


Fig. 6.

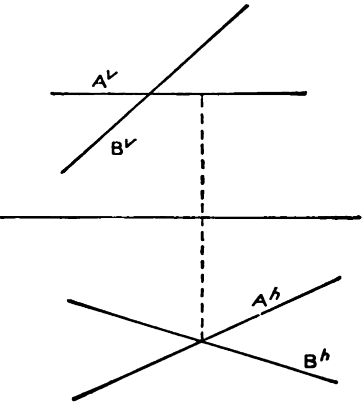


Fig. 7.

If two lines intersect, their projections must cross, since the point of intersection of the lines is a point on both lines, and therefore the projections of this point must be on the projections of both lines, or at their intersection. In order that intersecting lines may be represented, the vertical projections must intersect in a point vertically above the intersection of the horizontal projections. Thus Fig. 6 represents two lines which do intersect as C^v crosses D^v at a point vertically above the intersection of C^h and D^h. In Fig. 7, however, the lines do not intersect since the intersections of their projections do not lie in the same vertical line.

In Fig. 8 is given the plan and elevation of a square pyramid standing on the horizontal plane. The height of the pyramid is the distance A B. The slanting edges of the pyramid, A C, A D, etc., must be all of the same length, since A is directly above the center of the base. What this length is, however, does not appear in either projection, as these edges are not parallel to either V or H.

Suppose that the pyramid be turned around into the dotted position C_1 D_1 E_1 F_1 where the horizontal projections of two of the slanting edges, A C_1 and A E_1 are parallel to the ground line. These two edges, having their horizontal projections parallel to the ground line, are now parallel to V, and therefore their new vertical projections will show their true lengths. The base of the pyramid is still on H, and therefore is projected on V in the ground line. The apex is in the same place as before, hence the vertical projection of the pyramid in its new position is shown by the dotted lines. The vertical projection A C_1^v is the true length of edge A C. Now if we wish to find simply the true length of A C, it is unnecessary to turn the whole pyramid around, as the one line A C will be sufficient.

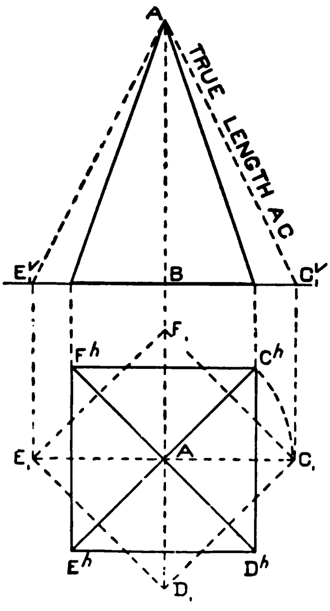
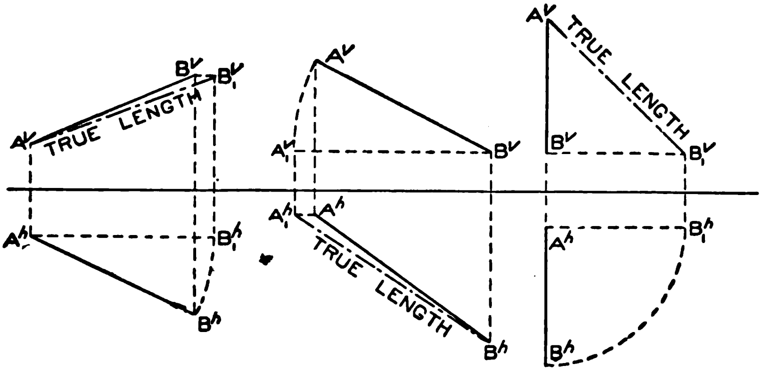


Fig. 8.

The principle of finding the true length of lines is this, and can be applied to any case: Swing one projection of the line parallel to the ground line, using one end as center. On the other projection the moving end remains at the same distance from the ground line, and of course vertically above or below the same end in its parallel position. This new projection of the line shows its true length. See the three Figures at the top of page 9.

Third plane of projection or profile plane. A plane perpendicular to both co-ordinate planes, and hence to the ground line, is called a *profile plane.* This plane is vertical in position, and may be used as a plane of projection. A projection on the profile plane is called a profile view, or *end view*, or sometimes edge view, and is often required in machine or other drawing when the plan and elevation do not sufficiently give the shape and dimensions.



A projection on this plane is found in the same way as on the V plane, that is, by perpendiculars drawn from points on the object.

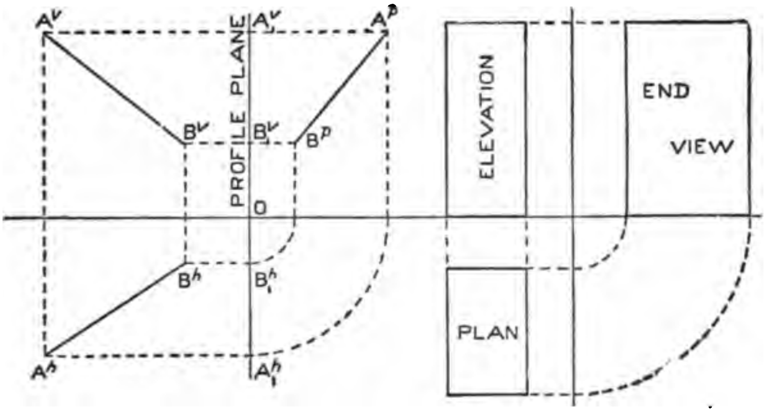


Fig. 9.

Since, however, the profile plane is perpendicular to the ground line, it will be seen from the front and top simply as a straight line; in order that the size and shape of the profile view may be shown, the profile plane is revolved into V using its intersection with the vertical plane as the axis.

Given in Fig. 9, the line A B by its two projections A^v B^v and A^h B^h, and given also the profile plane. Now by projecting the line on the profile by perpendiculars, the points A_1^v B_1^v and B_1^h A_1^h are found. Revolving the profile plane like a door on its hinges, all points in the plane will move in horizontal circles, so the horizontal projections A_1^h and B_1^h will move in arcs of circles with O as center to the ground line, and the vertical projections B_1^v and A_1^v will move in lines parallel to the ground line to positions directly above the revolved points in the ground line, giving the profile view of the line A^p B^p. Heights, it will be seen, are the same in profile view as in elevation. By referring to the rectangular prism in the same figure, we see that the elevation gives vertical dimensions and those parallel to V, while the end view shows vertical dimensions and those perpendicular to V. The profile view of any object may be found as shown for the line A B by taking one point at a time.

In Fig. 10 there is represented a rectangular prism or block, whose length is twice the width. The elevation shows its height. As the prism is placed at an angle, three of the vertical edges will be visible, the fourth one being invisible.

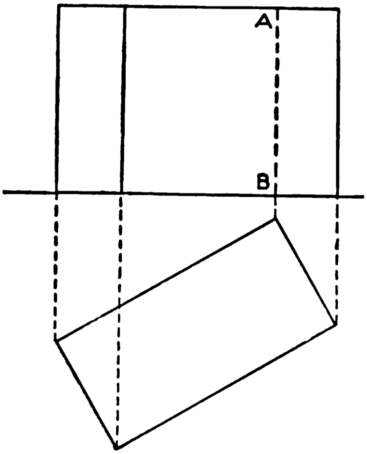


Fig. 10.

In mechanical drawing lines or edges which are invisible are drawn *dotted*. The edges which in projection form a part of the outline or contour of the figure must always be visible, hence always *full lines*. The plan shows what lines are visible in elevation, and the elevation determines what are visible in plan. In Fig. 10, the plan shows that the dotted edge A B is the back edge, and in Fig. 11, the dotted edge C D is found, by looking at the elevation, to be the lower edge of the triangular prism. In general, if in elevation an edge projected *within* the figure is a back edge, it must be dotted, and in plan if an edge projected within the outline is a lower edge it is dotted.

Fig. 12 is a circular cylinder with the length vertical and with a hole part way through as shown in elevation. Fig. 13 is plan, elevation and end view of a triangular prism with a square hole from end to end. The plan and elevation alone would be insufficient to determine positively the shape of the hole, but the end view shows at a glance that it is square.

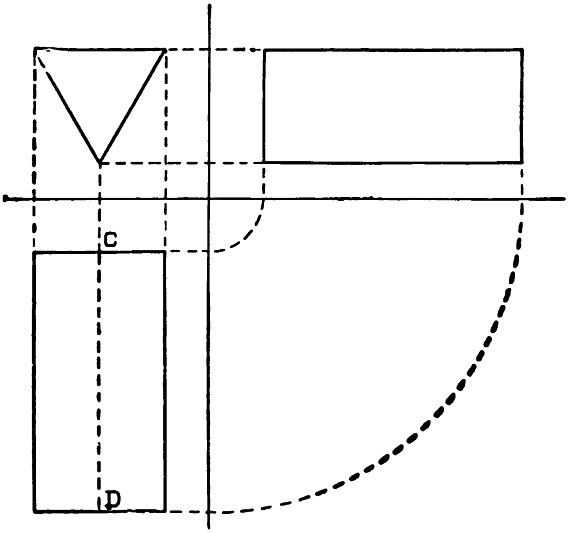


Fig. 11.

In Fig. 14 is shown plan and elevation of the frustum of a square pyramid, placed with its base on the horizontal plane. If the frustum is turned through 30°, as shown in the plan of Fig. 15, the top view or plan must still be the same shape and size, and as the frustum has not been raised or lowered, the heights of all points must appear the same in elevation as before in Fig. 14. The elevation is easily found by projecting points up from the plan, and projecting the height of the top horizontally across from the first elevation, because the height does not change.

The same principle is further illustrated in Figs. 16 and 17. The elevation of Fig. 16 shows a square prism resting on one edge, and raised up at an angle of 30° on the right-hand side. The plan gives the width or thickness, ⅝ in. Notice that the length of the plan is greater than 2 in. and that varying the angle at

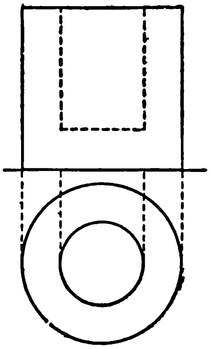


Fig. 12.

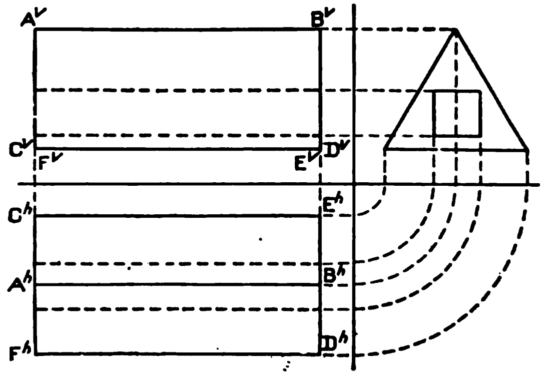


Fig. 13.

which the prism is slanted would change the length of the plan. Now if the prism be turned around through any angle with the vertical plane, the lower edge still being on H, and the inclination

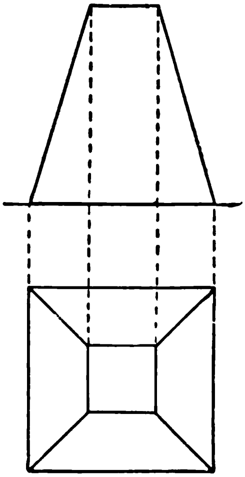


Fig. 14.

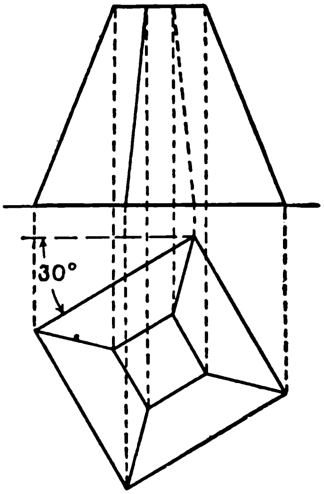


Fig. 15.

of 30° with H remaining the same, the plan must remain the same size and shape.

If the angle through which the prism be turned is 45°, we have the second plan, exactly the same shape and size as the first. The elevation is found by projecting the corners of the prism vertically up to the heights of the same points in the first elevation. All the other points are found in the same way as point No. 1.

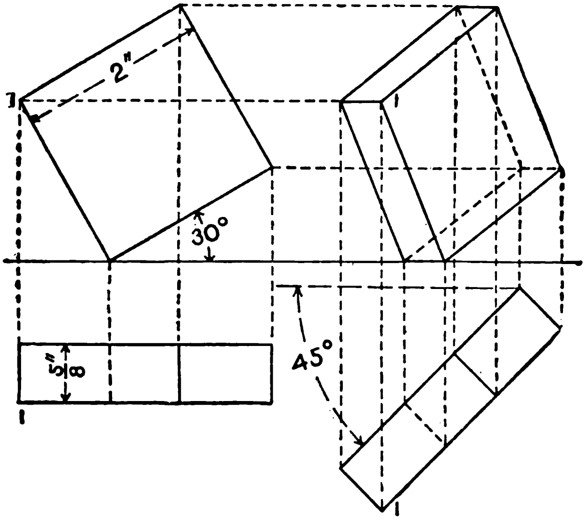


Fig. 16.

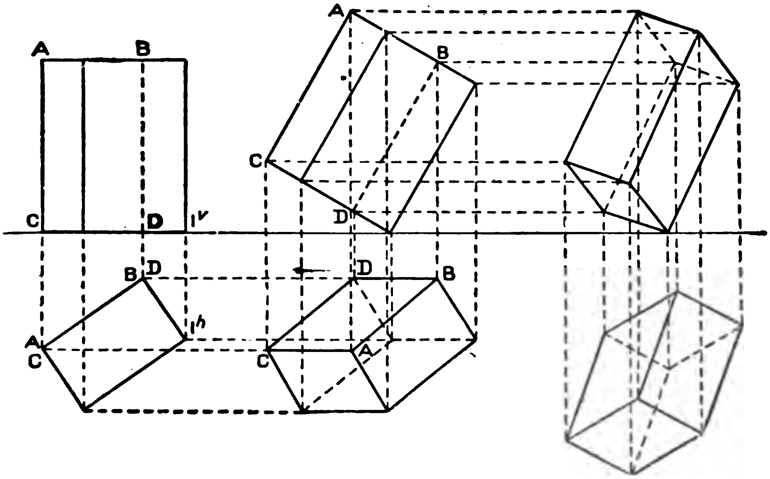


Fig. 17.

Three positions of a rectangular prism are shown in Fig. 17. In the first view, the prism stands on its base, its axis therefore is parallel to the vertical plane. In the second position, the axis is still parallel to V and one corner of the base is on the horizontal plane. The prism has been turned as if on the line 1^h 1^v as an axis, so that the inclination of all the faces of the prism to the vertical plane remains the same as before. That is, if in the first figure the side A B C D makes an angle of 30° with the vertical, the same side in the second position still makes 30° with the vertical plane. Hence the elevation of No. 2 is the same shape and size as in the first case. The plan is found by projecting the corners down from the elevation to meet horizontal lines projected across from the corresponding points in the first plan. The third position shows the prism with all its faces and edges making the same angles with the horizontal as in the second position, but with the plan at a different angle with the ground line. The plan then is the same shape and size as in No. 2, and the elevation is found by projecting up to the same heights as shown in the preceeding elevation. This principle may be applied to any solid, whether bounded by plane surfaces or curved.

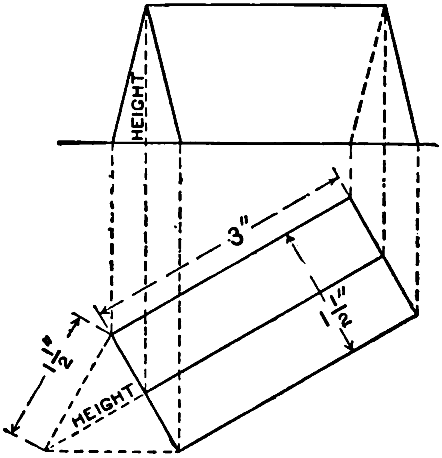


Fig. 18.

This principle as far as it relates to heights, is the same that was used for profile views. An end view is sometimes necessary before the plan or elevation of an object can be drawn. Suppose that in Fig. 18 we wish to draw the plan and elevation of a triangular prism 3″ long, the end of which is an equilateral triangle

$1\frac{1}{2}''$ on each side. The prism is lying on one of its three faces on H, and inclined toward the vertical plane at an angle of 30°. We are able to draw the plan at once, because the width will be $1\frac{1}{2}$ inches, and the top edge will be projected half way between the other two. The length of the prism will also be shown. Before we can draw the elevation, we must find the height of the top edge. This height, however, must be equal to the altitude of the triangle forming the end of the prism. All that is necessary, then, is to construct an equilateral triangle $1\frac{1}{2}''$ on each side, and measure its altitude.

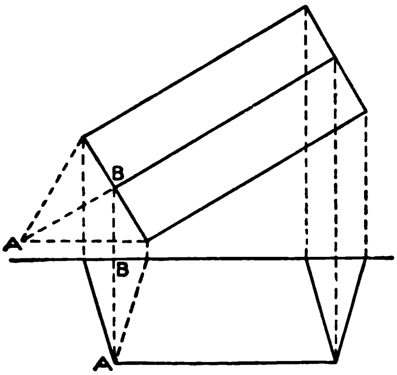


Fig. 19.

A very convenient way to do this is shown in the figure by laying one end of the prism down on H. A similar construction is shown in Fig. 19, but with one face of the prism on V instead of on H.

In all the work thus far the plan has been drawn below and the elevation above. This order is sometimes inverted and the plan put above the elevation.

PLATES.

PLATE V.

The plates of this paper should be laid out the same size as the plates in Part I. The center lines and border lines should also be drawn as shown.

First draw two ground lines across the sheet, 3 inches below the upper border line and 3 inches above the lower border line. The first problem on each ground line is to be placed 1 inch from the left border line and spaces of about 1 inch should be left between the figures.

Isolated points are indicated by a small cross ×, and projections of lines are to be drawn full unless invisible. All construction lines should be fine dotted lines. Given and required lines should be drawn full.

Problems on upper ground line;

PROBLEM 1. Locate both projections of a point on the horizontal plane 1 inch from the vertical plane.

PROBLEM 2. Draw the projections of a line 2 inches long which is parallel to the vertical plane and makes an angle of 45 degrees with the horizontal and slants upward to the right.

The line should be 1 inch from the vertical plane and the lower end $\frac{1}{2}$ inch above the horizontal.

PROBLEM 3. Draw the projections of a line $1\frac{1}{2}$ inches long, which is parallel to both planes 1 inch above the horizontal and $\frac{3}{4}$ inch from the vertical.

PROBLEM 4. Draw the plan and elevation of a line 2 inches long which is parallel to H and makes an angle of 30 degrees with V. Let the right-hand end of the line be the end nearer V, $\frac{1}{2}$ inch from V. The line to be 1 inch above H.

PROBLEM 5. Draw the plan and elevation of a line $1\frac{1}{2}$ inches long which is perpendicular to the horizontal plane and 1 inch from the vertical. The lower end of line is $\frac{1}{2}$ inch above H.

PROBLEM 6. Draw the projections of a line 1 inch long which is perpendicular to the vertical plane and $1\frac{1}{2}$ inch above the horizontal. The end of the line nearer V, or the back end, is $\frac{1}{2}$ inch from V.

PROBLEM 7. Draw two projections which shall represent a line oblique to both planes..

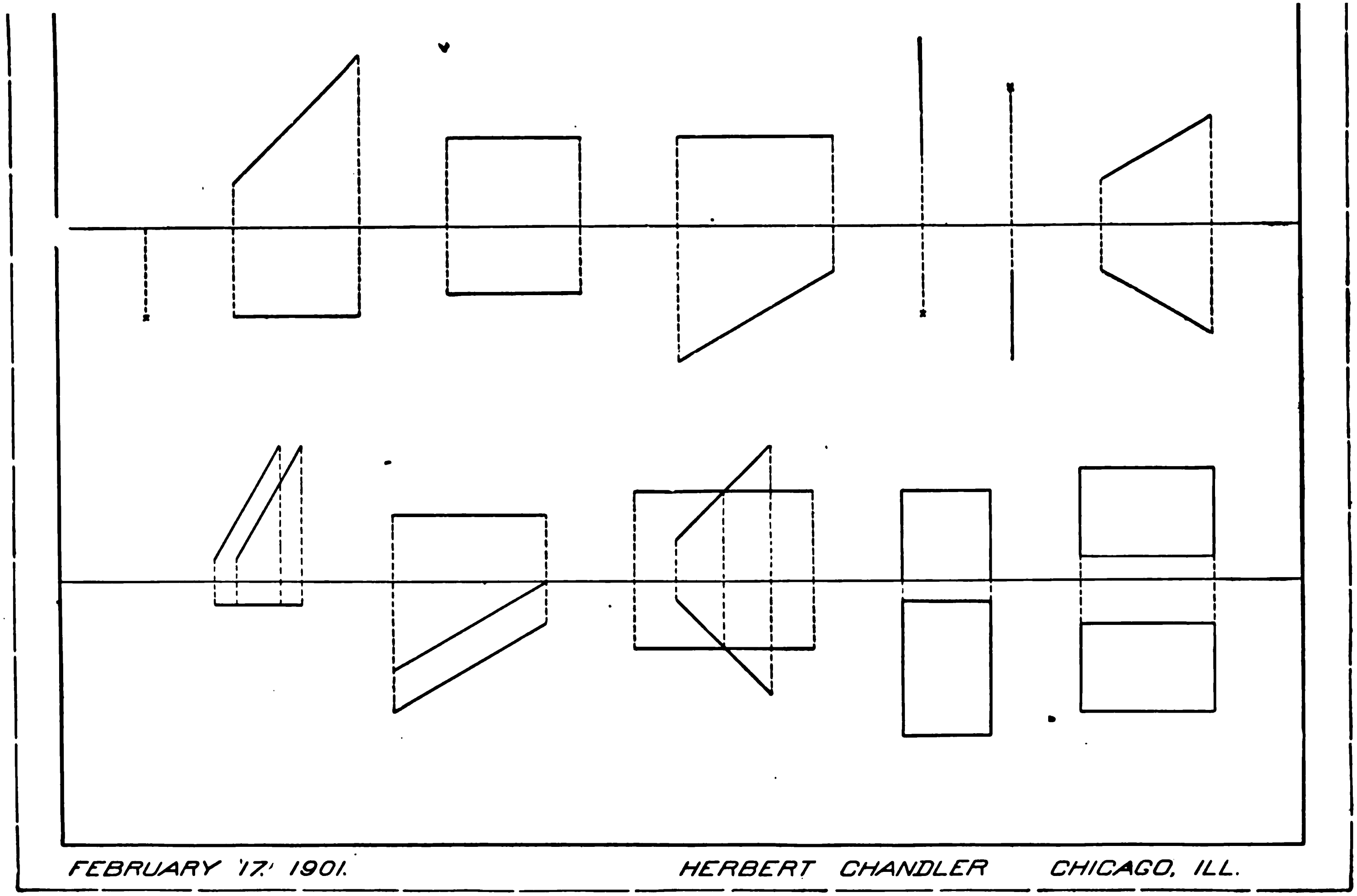
NOTE: Leave 1 inch between this figure and the right-hand border line.

Problems on lower ground line.

PROBLEM 8. Draw the projections of two parallel lines each $1\frac{1}{2}$ inches long. The lines are to be parallel to the vertical plane and make angles of 60 degrees with the horizontal. The lower end of each line is $\frac{1}{4}$ inch above H. The right-hand end of the right-hand line is to be $2\frac{3}{4}$ inches from the left-hand margin.

PROBLEM 9. Draw the projections of two parallel lines each 2 inches long. Both lines to be parallel to the horizontal and make an angle of 30 degrees with the vertical. The lower line to be $\frac{3}{4}$ inch above H and one end of one line to be against V.

PROBLEM 10. Draw the projections of two intersecting lines. One 2 inches long to be parallel to both planes 1 inch



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above H and ¾ inch from the vertical, and the other to be oblique to both planes and of any desired length.

PROBLEM 11. Draw plan and elevation of a prism 1 inch square and 1½ inches long. The prism to have one side on the horizontal plane and the long edges perpendicular to V. The back end of the prism is ¼ inch from the vertical plane.

PROBLEM 12. Draw plan and elevation of a prism the same size as given above, but with the long edges parallel to both planes, the lower face of prism parallel to H and ¼ inch above it. The back face to be ½ inch from V.

PLATE VI.

The ground line is to be in the middle of the sheet, and the location and dimensions of the figures are to be as given. The first figure shows a rectangular block with a rectangular hole cut through from front to back. The other two figures represent the same block in different positions. The second figure is the end or profile projection of the block. The same face is on H in all three positions. Be careful not to omit the shade lines, and try to see why each one is put on.

PLATE VII.

Three ground lines are to be used on this plate, two at the left, 4½″ long and 3″ from top and bottom margin lines, and one at the right, half way between the top and bottom margins, 9½″ long.

The figures 1, 2, 3 and 4 are examples for finding the true lengths of the lines. Begin No. 1 ¾″ from the border, the vertical projection 1¾″ long, one end on the ground line, and inclined at 30°. The horizontal projection has one end ½″ from V and the other 1½″ from V. Find the true length of the line by completing the construction commenced by swinging the arc, as shown in the figure.

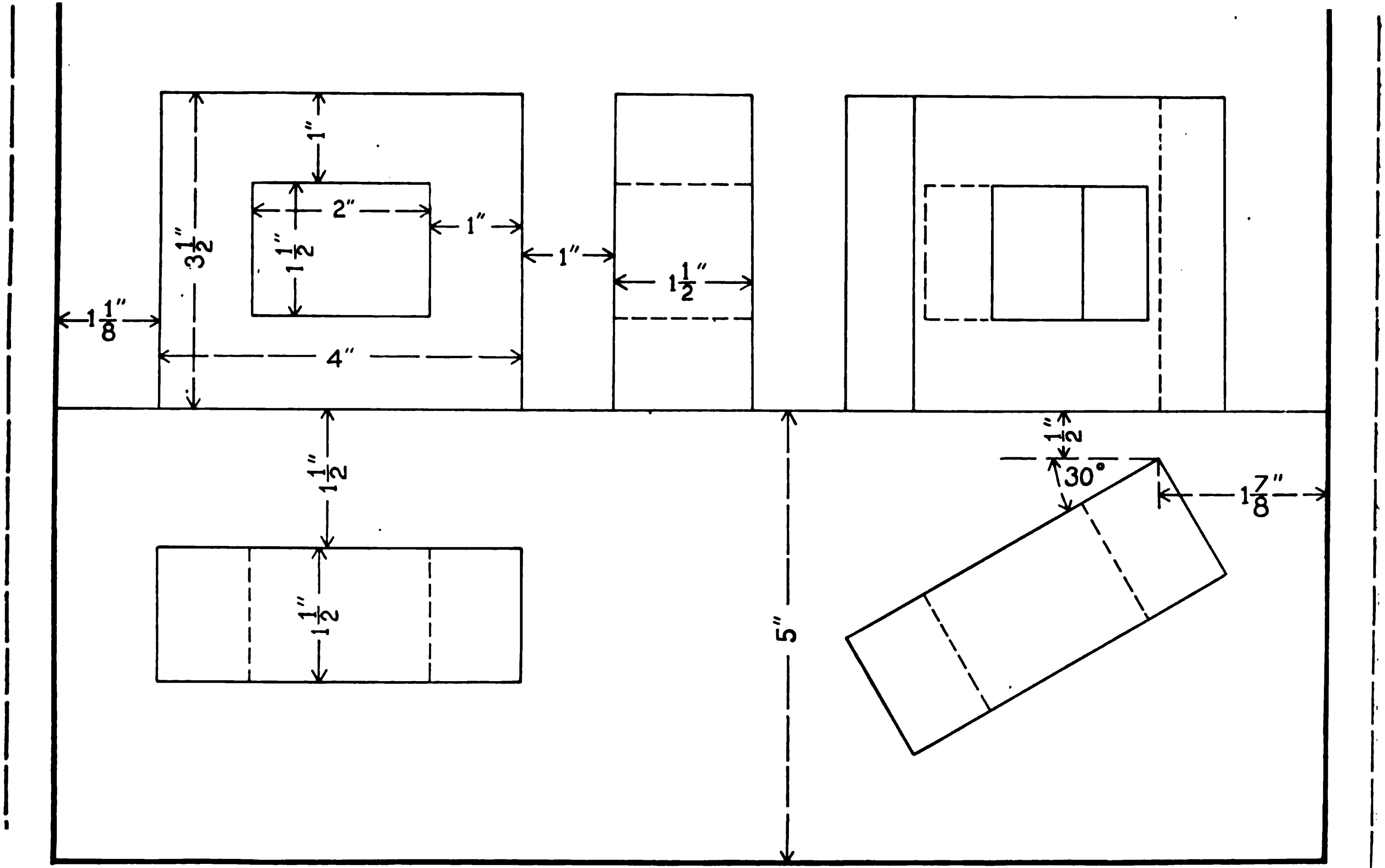
Locate the left-hand end of No. 2 3″ from the border, 1″ above H and ⅝″ from V. Extend the vertical projection to the ground line at an angle of 45°, and make the horizontal projection at 30°. Complete the construction for true length as commenced in the figure.

In figures 3 and 4 the true lengths are to be found by completing the revolutions indicated. The left-hand end of Fig. 3 is $\frac{3}{4}''$ from the margin, $1\frac{1}{2}''$ from V and $1\frac{3}{8}''$ above H. The horizontal projection makes an angle of 60° and extends to the ground line, and the vertical projection is inclined at 45°.

The fourth figure is $3''$ from the border and represents a line in a profile plane connecting points *a* and *b*. *a* is $1\frac{1}{4}''$ above H and $\frac{3}{4}''$ from V, and *b* is $\frac{1}{4}''$ above H and $1\frac{1}{2}''$ from V.

The figures for the middle ground line represent a pentagonal pyramid in three positions. The first position is the pyramid with the axis vertical and base $\frac{5}{8}''$ above the horizontal. The height of pyramid is $2\frac{1}{2}''$ and the diameter of the circle circumscribed about the base is $2\frac{1}{2}''$. The center of the circle is $6''$ from the left margin and $1\frac{3}{4}''$ from V. Spaces between figures to be $\frac{3}{4}''$.

In the second figure the pyramid has been revolved about the right-hand corner of the base as an axis through an angle of 15°. The axis of the pyramid, shown dotted, is therefore at 75°. The method of obtaining 75° and 15° with the triangles was shown in Part I. From the way in which the pyramid has been revolved, all angles with V must remain the same as in the first position, hence the vertical projection will be the same shape and size as before. The points on the plan are found on T-square lines through the corners of the first plan and directly beneath the points in elevation. In the third position the pyramid has been swung around about a vertical line through the apex as axis through 30°. The angle with the horizontal plane remains the same, consequently the plan is the same size and shape as in the second position, but at a different angle with the ground line. Heights of all points of the pyramid have not changed this time, and hence are projected across from the second elevation. Shade lines are to be put on between the light and dark surfaces as determined by the 45° triangle.



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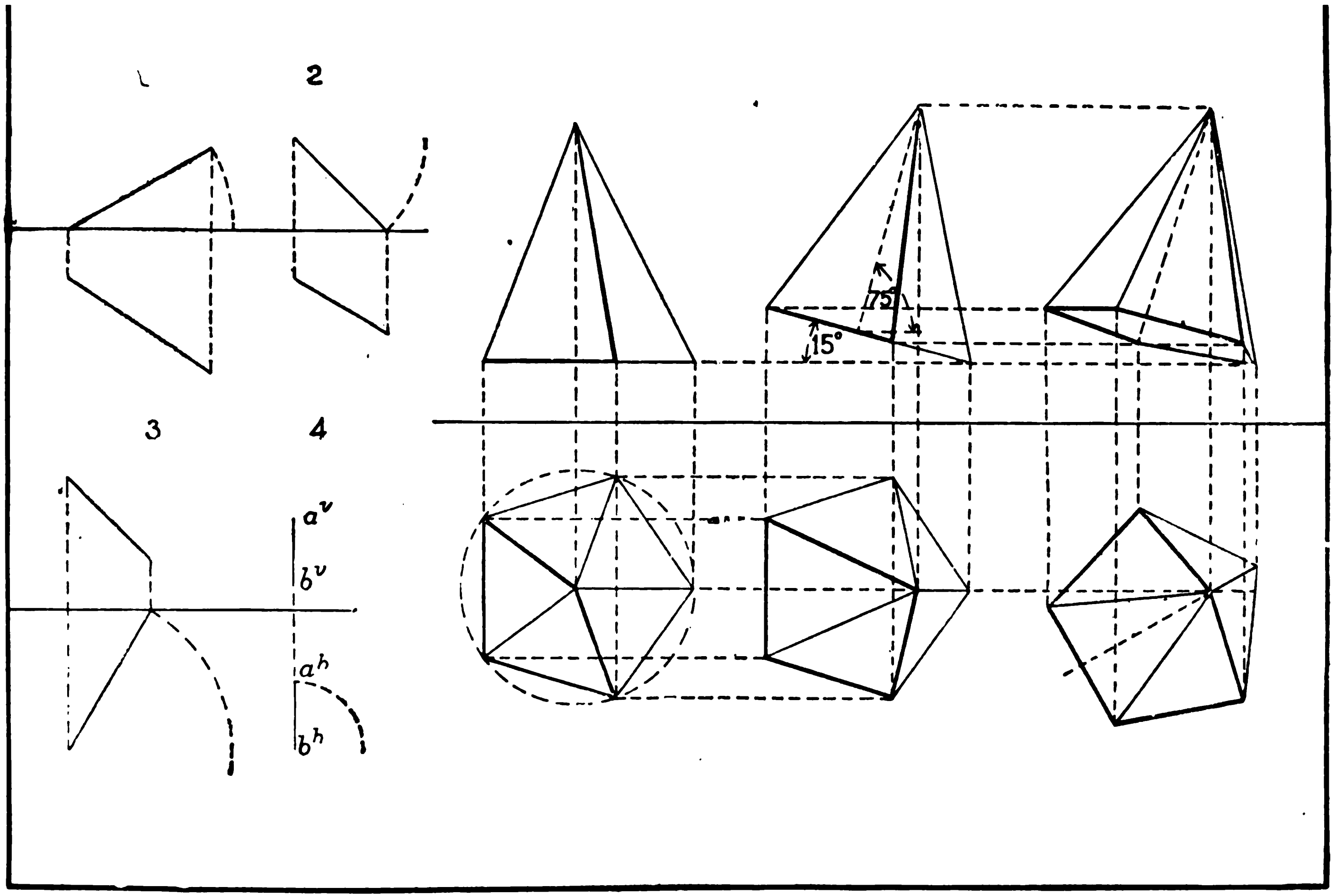

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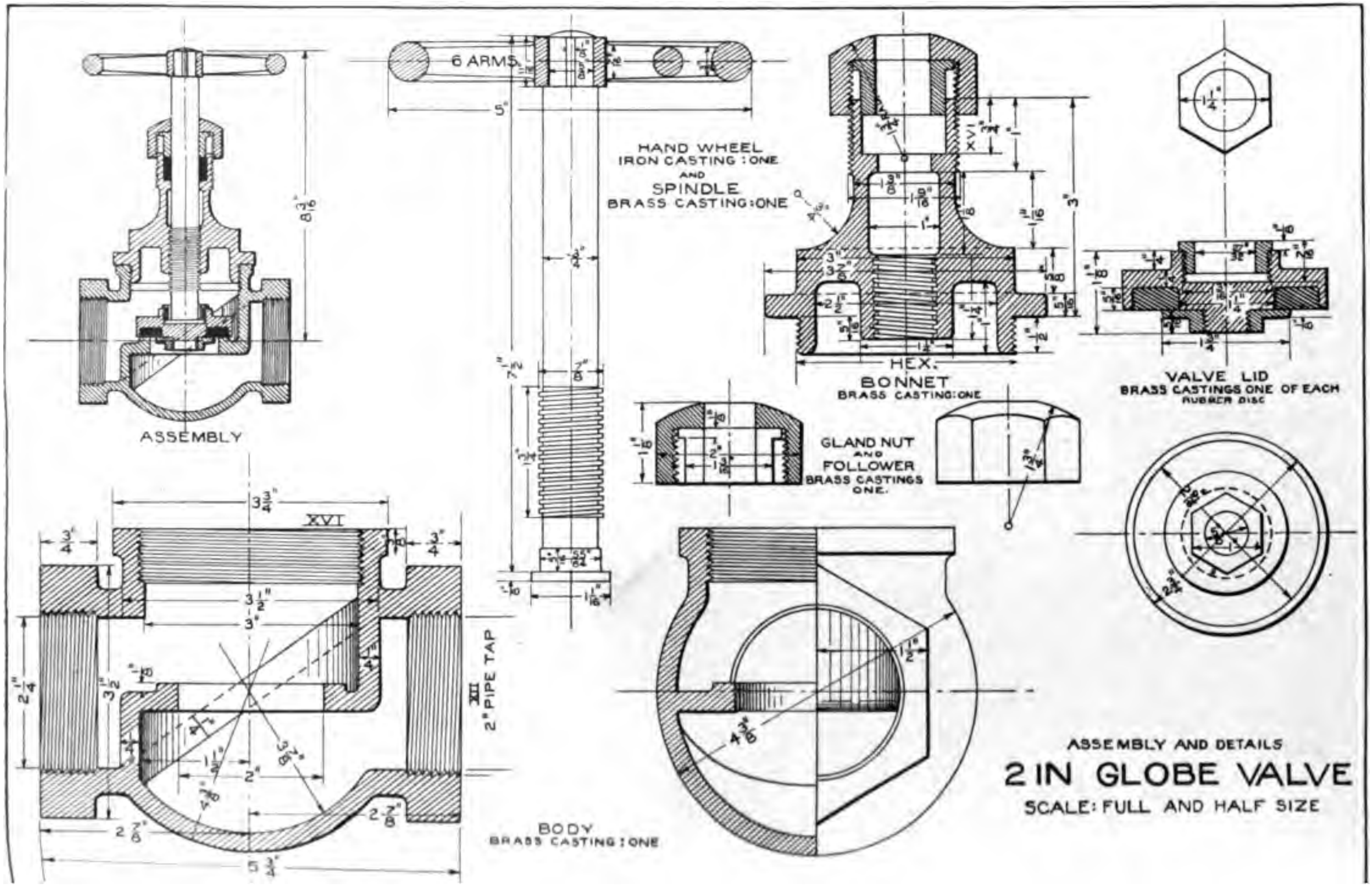


ASSEMBLY AND DETAILS

2 IN GLOBE VALVE

SCALE: FULL AND HALF SIZE

MECHANICAL DRAWING.

PART III.

WORKING DRAWINGS.

In Mechanical Drawing Parts I and II, instruments and materials are described and some hints given regarding the use of compasses, line pen, triangles, T-square, etc. In addition, the general principles upon which all Mechanical Drawing depends, are explained. After completing this work the student should be able to draw neatly and accurately and apply the fundamental principles.

Let us now take up the subject of working drawings and see how the principles of orthographic projection are made of practical use. We shall see, as we go on, that to a great extent the theoretical principles already learned in the study of projections are used in practical working shop drawings. Nevertheless, there are certain instances in which actual practice differs slightly from the theory.

We shall also find that all draftsmen do not follow the same customs in the matter of minor details, but that in many cases there are several ways of representing objects, all of which may be equally correct, one draftsman using one method either because he prefers it or because it best serves the purpose for which his particular work is being done, while another draftsman uses a different method. The more important principles and customs, however, are pretty well established.

A study of the subject of working drawings should, first, teach us the methods of the best drafting rooms; second, should train our judgment to decide how best to represent the particular object which we have to draw; third, should train our hand and eye to make a clear, neat and well-executed drawing, without unnecessary expenditure of time.

Definition of Working Drawing. A working drawing of any object is a drawing which completely describes the object in every particular, showing its form, size, material, finish, and all other details, so that a workman may take the drawing and without any further instructions make the object exactly as the draftsman intended it to be made. The drawing is, therefore, a sort of language, by which the man who designs the object describes it to the man who is to make it. Fig. 1 shows the working drawing of a bell crank lever. The drawing itself shows the shape and the dimensions show the size.

Aside from drawings of buildings, etc., that is Architectural drawings, the greater part of the working drawings which are made are for machines, and we will consider chiefly the latter, or, as they are called, machine drawings. These drawings are almost always orthographic projections, as this is by far the easiest and best way to represent a machine or a part of a machine. Sometimes, when it is desired to give a sort of bird's-eye view of a machine, an isometric or an oblique projection is made, but this method involves so much labor that it is seldom used.

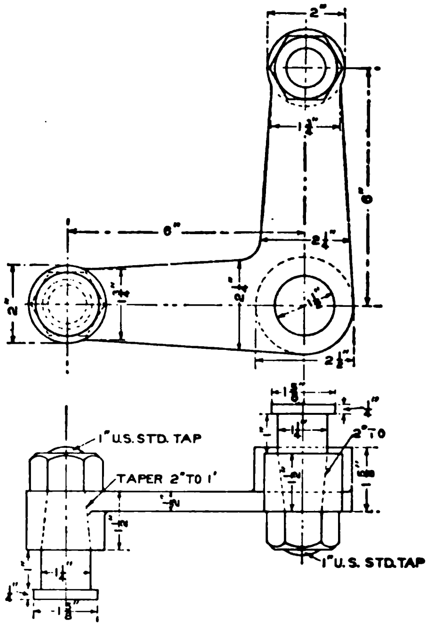


Fig. 1.

Lines. In order to make a drawing perfectly clear, and to avoid confusing one line with another, different kinds of lines are used for different purposes. Fig. 2 shows the six most common kinds used. The ordinary *full lines* are used to represent visible lines of the object which is being drawn.

The *invisible lines* are used to represent lines of the object which would be hidden from sight if a person looked in the direction in which he imagines himself to be looking while he is drawing it.

The use of the *shade lines* will be explained later.

Center lines are used to connect different views of an object, the line being drawn through the center of the piece and extending through both views. Locations of holes are usually shown by having two center lines drawn at right angles to each other through their centers, and the position of these center lines located. Wherever a dimension is to be given to the center of a piece a center line is drawn through the piece and the dimension given to this line.

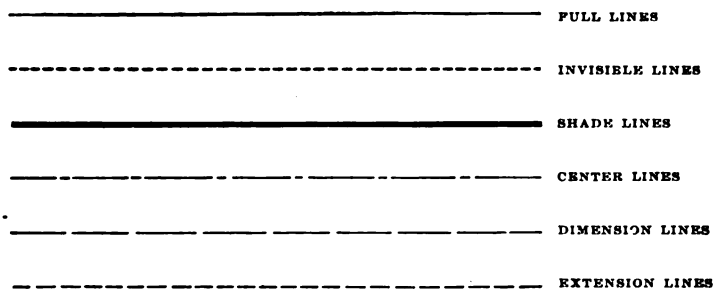


Fig. 2.

Extension lines are sometimes used to connect two views of a piece, but, wherever it is possible to use a center line, instead, the latter is preferable. The principal use of extension lines is, as the name implies, to extend the lines of the object so as to give dimensions between them.

Dimension lines are used in giving dimensions from one line or point to another.

The ordinary lines and the invisible lines should be made of the same width; the shade lines should be made considerably heavier, and the center lines, extension lines and dimension lines should be lighter.

Location of Views. In our preceding study of projections we imagined our object to be held in the angle formed by two planes which intersect at right angles, the planes and the object being supposed to be in the position represented in Fig. 3, the horizontal plane H being below the object, and the vertical plane V being beside the object. We then projected down to the horizontal plane and represented there the object as it would appear if seen squarely in the direction indicated by arrow A. We next projected into the vertical plane, and represented the object as it would appear if the line of vision took the direction of the arrow B. Our planes, with the horizontal and vertical projections of the object on them, when laid out flat, as a sheet of paper is when we actually draw on it, would appear as in Fig. 4, the horizontal projection. or top view, being *underneath* the vertical projection, or side view. This is the practice followed by some draftsmen in making working drawings. Many of the best draftsmen, however, think that it is not as clear and convenient to have the top view of the object underneath the side view, but that it is better to have the view of the top above the other view. Consequently, it is becoming more and more a general custom to suppose the planes to be transparent and to be located with respect to the piece which is being drawn as shown in Fig. 5, the H plane being above the object and the V plane in front of the object. They then draw on the H plane the object as it appears when looking at it

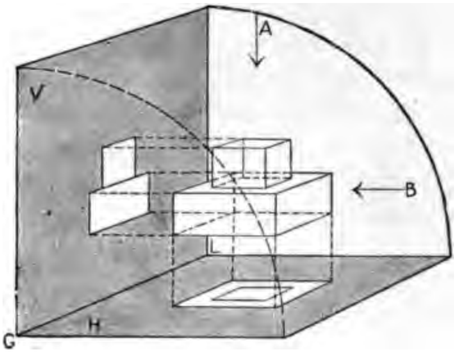


Fig. 3.

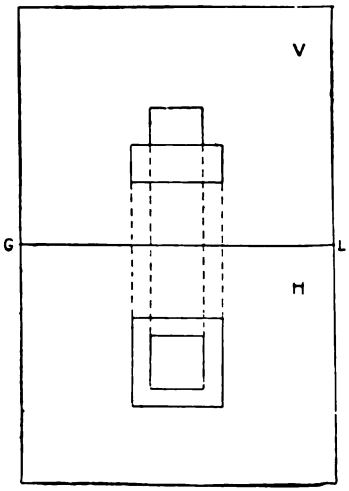


Fig. 4.

through the transparent plane in the direction indicated by arrow C, and on the V plane the object as it appears when looking in direction of arrow D. Now, when the two planes are laid out flat, the top view is above the side view, as in Fig. 6.

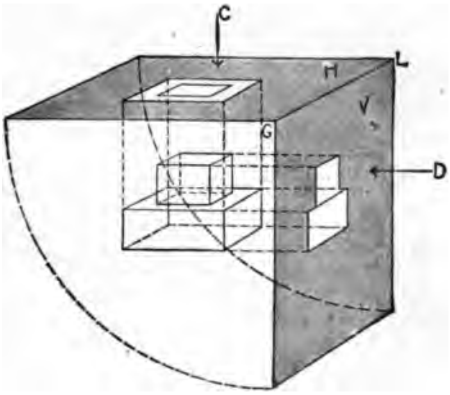


Fig. 5.

Another way of showing this is to suppose the object to be located in a transparent box, and that we look at it from the top and the various sides of the box, and draw on these sides the object as it appears from that side. Then, if the sides of the box are laid out flat, the side view will come in the middle, with the top view above, the view of the bottom underneath, the view of the right-hand side on the right, and the view of the left-hand side on the left.

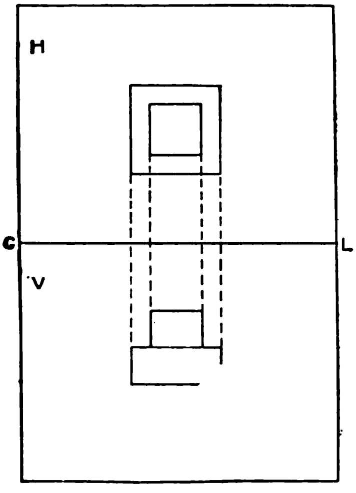


Fig. 6.

From now on, in our work on drawing, we shall follow this rule.

Cross-sections. Very often it occurs that a piece is hollow and the inside construction is more or less complicated, so that if in the drawing the outside view is shown, with the invisible interior drawn in dotted lines, the latter are so confused that the drawing is not easily understood. For this reason it is often convenient to imagine the piece to be cut open, and to draw it as if we were looking directly at the inside. Such a drawing of a piece is called a cross-section of the piece. The material which must be cut if the object were actually split open is then crosshatched, different kinds of crosshatching being used for different materials. Fig. 7 shows the kinds of cross-hatching in ordinary use.

Fig. 8 shows a plan and elevation of a simple piece with a hole through it, the hole being shown in the elevation by dotted lines. Fig. 9 shows a plan and a cross-section of the same piece, the cross-section being drawn as if we were looking in the same direction as in the elevation of Fig. 8, but in Fig. 9 the front half is supposed to be cut away and we are looking at the inside of the back half. It will be observed that even on a piece as simple as the one here shown, the shape of the interior is much clearer from the cross-section than from the elevation, and on a more complicated piece the same will be true to a greater extent.

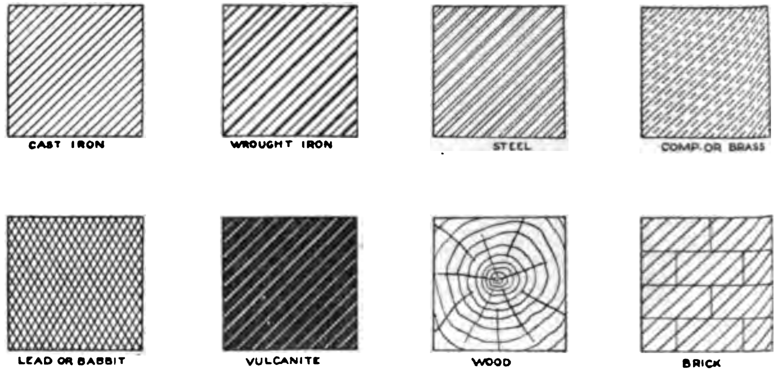


Fig. 7.

It should be borne in mind that ordinarily in making a cross-section we show not only those parts of the object which lie in the plane in which it is supposed to be cut, but also all which lie back of that plane.

Sometimes it is desirable to show the inside and the outside of a piece on the same view. Fig. 10 shows the same piece as in Fig. 8, but in Fig 10 the left-hand half of the lower view is an elevation and the right-hand half is a cross-section, the section and the elevation each extending to the center and being separated by a center line. This is as if one-quarter of it were cut away, the cuts being made along the lines C A and C B of the plan view.

Of course this combination of an elevation and cross-section can be used only when the right-hand and left-hand halves of the piece are alike.

Shade Lines. In order to make drawings easier to read, and to make the parts of the object stand out more clearly, shade lines are often put on the drawing. The general principle which determines what lines shall be shade lines is the same as that which governs shade lines already studied under the subject of projections. If, however, this theoretical principle were to be followed out exactly on drawings of machines, and other complicated drawings, it would involve a great deal of time and labor.

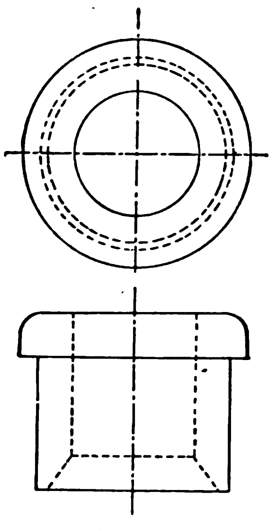


Fig. 8.

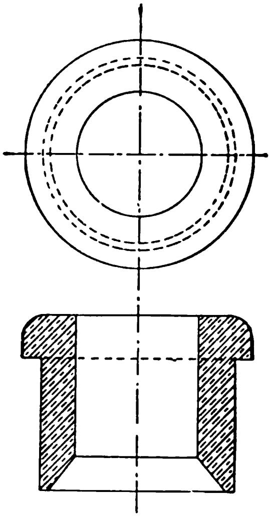
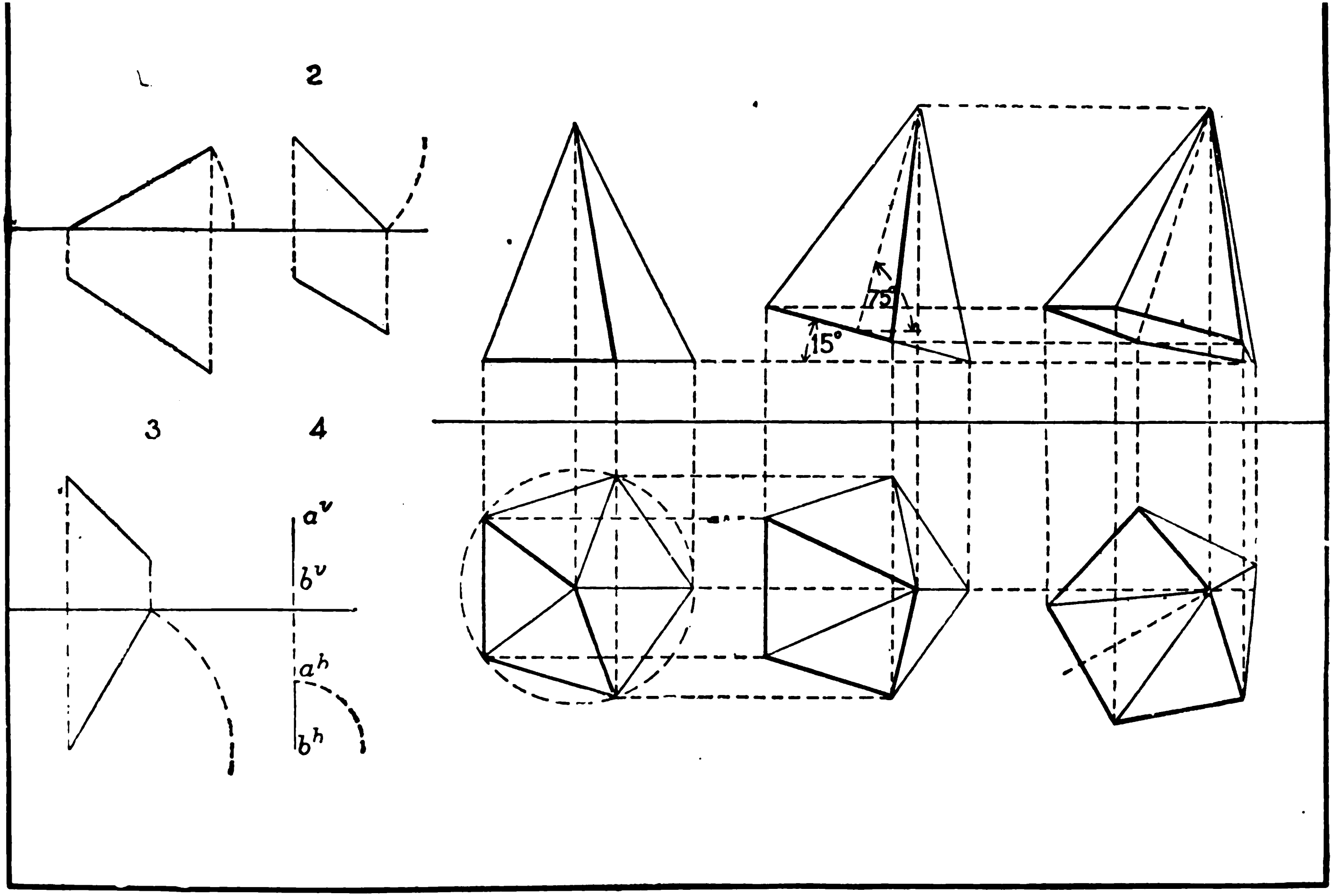


Fig. 9.

Consequently, most draftsmen place shade lines on all lines which represent lower and right-hand edges if these edges are sharp.

The contour lines of cylinders, cones and other rounded surfaces should not be shade lines, although some draftsmen shade them. If the cylinder is drawn in cross-section, however, the edge should be shaded, as the intersection of the plane and cylindrical surface is a sharp edge.

All views are shaded alike, and both are shaded as though they were elevations. The ray of light is supposed to come over



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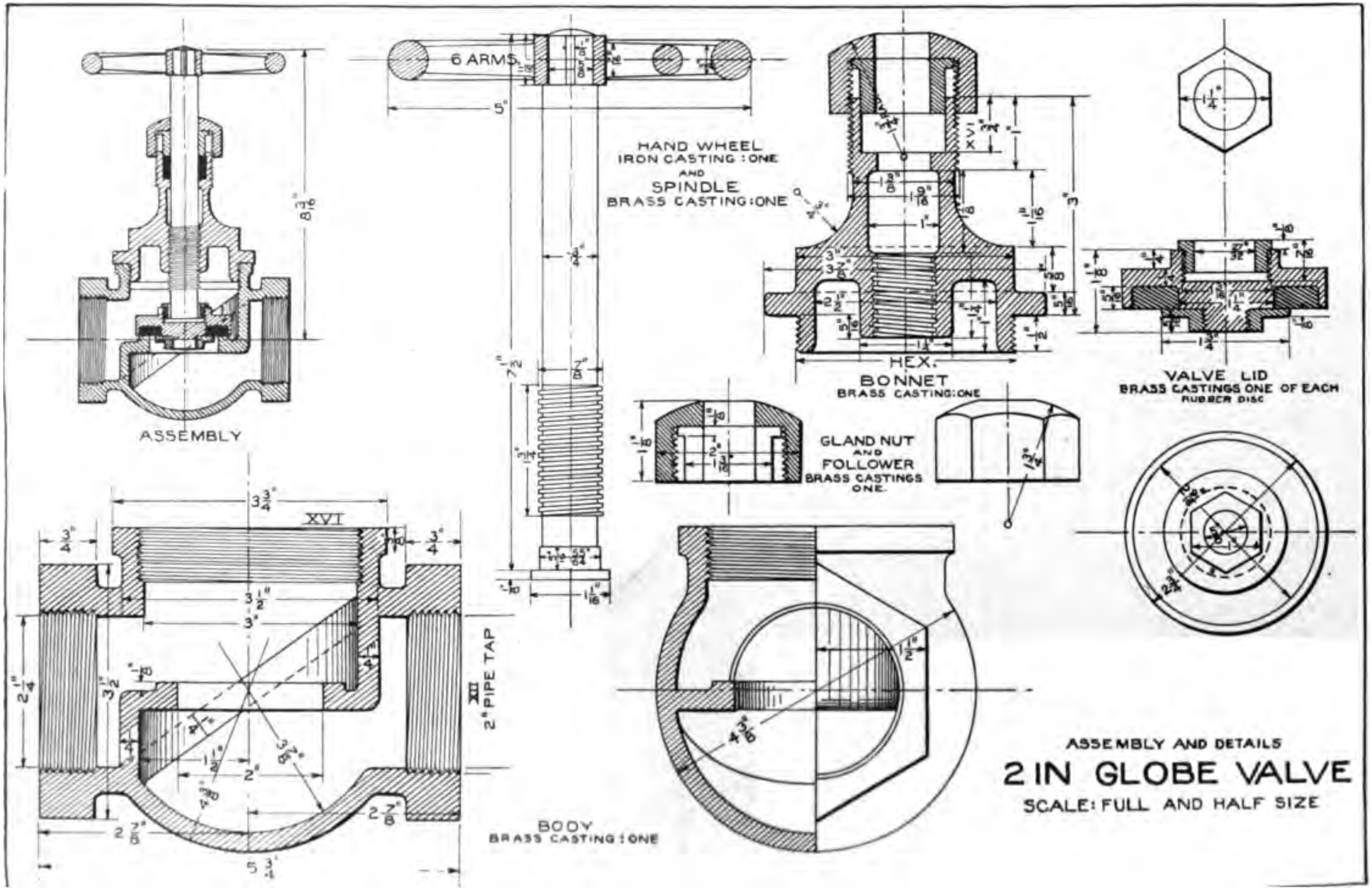

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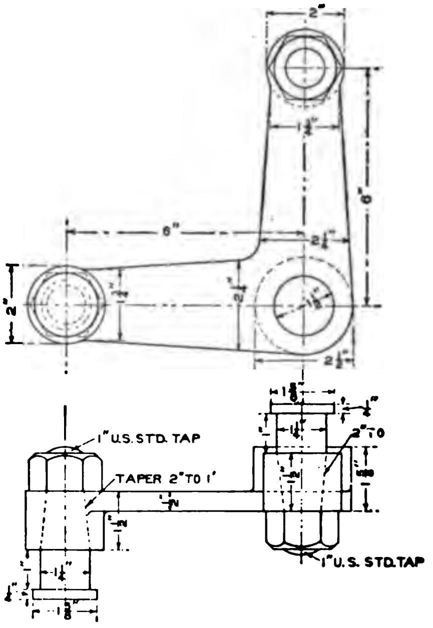

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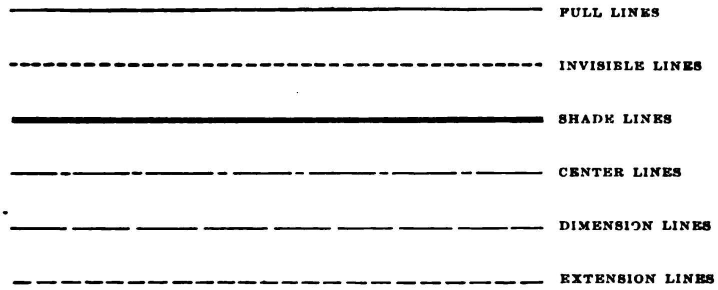

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Location of Views. In our preceding study of projections we imagined our object to be held in the angle formed by two center line circle through their centers and giving the diameter of this circle, and if no other dimension than this is given for the location of the holes, it is understood that they are equally spaced around this circle. Fig. 21 illustrates this. If the holes are not equally spaced around the circle, they may be located as shown in Fig. 22.

Diameters of circles, and of arcs of circles which are greater than semicircles, should be given rather than radii, but if the arc of the circle is less than a semicircle, its radius should be given. Fig. 23 shows how this should be done when the radius is large enough to permit; but if the radius is small, or the dimensions would interfere with other parts of the drawing, it may be done as in Fig. 24.

In Fig. 23 a small circle is drawn (free hand) around the center about which the arc is drawn, and a dimension line carried from the edge of this circle to the arc; an arrowhead being placed on the arc, and the figures placed in the dimension line in the usual way. In this case it is not necessary to put the letter R (abbreviation for radius) after the dimension. In the two methods shown in Fig. 24 the R should be placed after the figures.

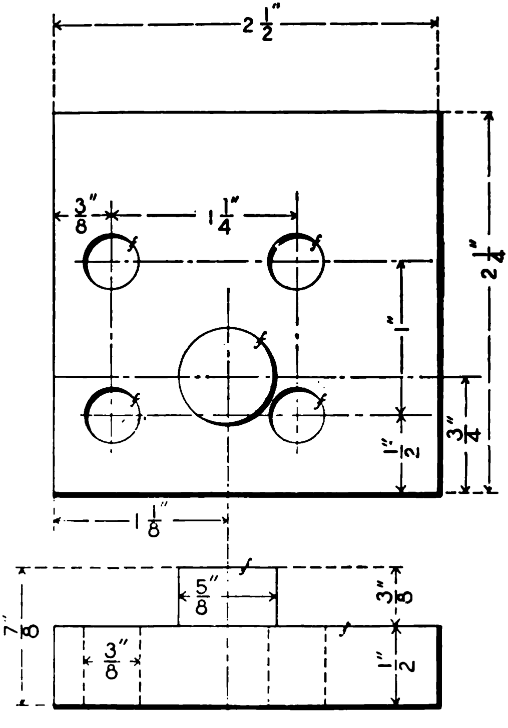

Fig. 20.

In putting dimensions on a drawing, the figures should be placed to read from only two sides of the paper, usually from the bottom for dimension lines which are horizontal, as the $2\frac{1}{2}''$ dimension in Fig. 20, and from the right hand for dimension lines which are vertical, as the $2\frac{1}{4}''$ dimension in the same figure. Dimensions should never be placed on center lines if it can be avoided.

If a dimension is given in one view of an object, the same dimension need not be repeated in the other views.

In putting on fractions it is better to have the line which divides the numerator and denominator of the fraction extend in the same direction as the dimension line rather than at an angle; that is, the fraction would appear thus, $\frac{1}{2}$, rather than $^1/_2$.

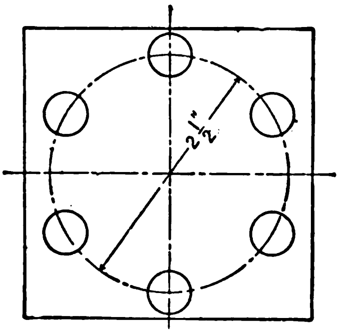

Fig. 21.

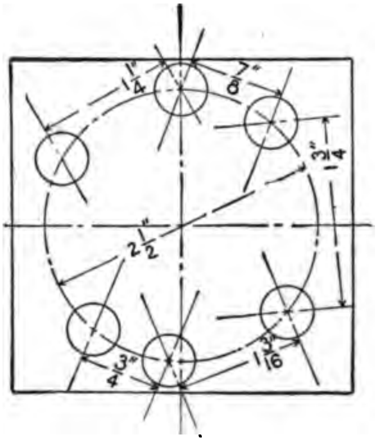

Fig. 22.

Finished Surfaces. Since a working drawing is not only to show the shape and size of the object which it represents, but is to describe it completely, it is essential that there should be some means of distinguishing between the surfaces of the object which are to be left rough as they come from the forge or from the foundry, and the surfaces which are to be finished. Any surface

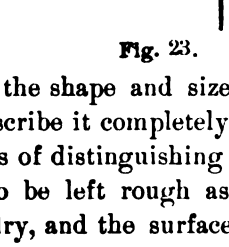

Fig. 23.

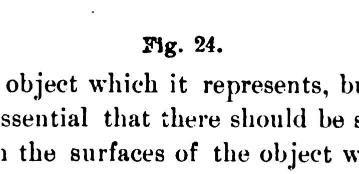

Fig. 24.

which has been smoothed off in a lathe, planer, or any machine tool, or has been filed or scraped, is called a finished surface, and is indicated on a drawing by a letter placed on the *edge view* of this surface. In Fig. 19 the whole of the cylindrical part is finished, also the top of the rectangular part. The holes are also finished. The student should notice carefully how the finish marks are used to indicate this fact.

If a piece is to be finished all over, it should be marked "*f* all over." If it is desired to specify what kind of finish is to be put on a surface, that is, whether rough turned, smooth turned, filed, scraped, etc., a note may be made to that effect.

On some conspicuous place on the drawing the words "*f* means finish" should be printed, so that there may be no misunderstanding on the part of a person examining the drawing.

Material. The material of which the piece is to be made should be indicated plainly. If any part of the drawing is a cross-section, the crosshatching might show the material, provided that in some conspicuous part of the drawing a sample of the crosshatching is shown and the material which it represents is stated. It is better, however, to mark on or near each piece, in plain letters, the material of which it is to be made.

Conventional Methods. In drafting, as in many other kinds of work, all unnecessary labor should be avoided. The drawing should give the instructions clearly, but need not be so elaborate as to require unnecessary time in the execution. It frequently happens that if an exact drawing were made representing every line of the object, a great deal of time would be required. Accordingly, if there is any way of representing an object by a few lines only, without sacrificing clearness, it should be used. There are many details such as screw threads, springs, bolts, etc., which occur so frequently on nearly all drawings that easy methods of representation have been universally adopted. In some cases, these ways of representing objects are approximations of the exact drawings and in other cases they are not. Such methods are called conventional methods, or conventions. For some details there is more than one convention, but the same convention should not be used for two different things, nor should several objects of the same kind on the same drawing be represented conventionally by two different methods.

Screw Threads. The exact drawing of screw threads is a difficult part of mechanical drawing, but enough attention will be given it here to enable the student to make a simple working drawing which includes threads. The common conventional way of drawing a thread is shown in Figs. 25, 26 and 27, Fig. 25 being a single right-hand thread, and Fig. 26 a double right-hand thread.

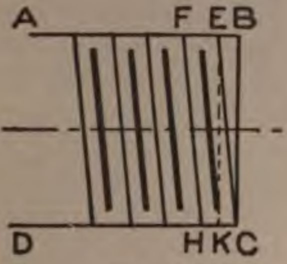

Fig. 25.

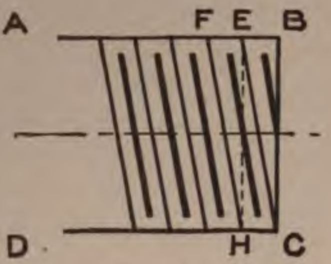

Fig. 26.

First, the plain cylindrical piece ABCD is drawn as if there were no threads upon it. The thread is then indicated by the lines EC, FH, etc., with the shorter and heavier lines between. The lighter lines are all parallel and the same distance apart. This distance is not necessarily the same as the actual pitch of the thread on the screw itself, but is usually $\frac{3}{32}$ inch or $\frac{1}{8}$ inch on drawings of common sizes of bolts. The heavy lines are parallel to the lighter ones and midway between them. The angle which the lines make with the center line of the screw depends on the distance apart of the lines, the slant being such that for a single thread, Fig. 25, a line perpendicular to the center line through one end of one of the lighter lines, as E, will strike the opposite contour of the screw DC, at a point K, which is half way between C and H. To draw the lines so that they will have this slant, choose the distance FE, which is to represent the pitch, and space it off on either of the contour lines, as AB, starting anywhere (in the figure the starting point E is one-half of the distance FE away from B). Next, draw EK per-

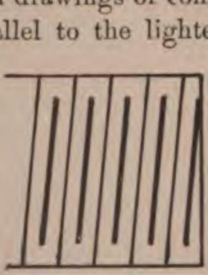

Fig. 27.

pendicular to the center line, thus finding point K, and start the spacing on the contour CD at a distance either side of K equal to ½ FE.

The lighter lines can thus be drawn and the heavy lines put in parallel and half way between. The heavy lines should be a little shorter than the others, and, for the sake of neatness, all should be of the same length. The double thread, Fig. 26, is drawn similarly to the single thread, except that the slant is such that the perpendicular through E will pass through H.

After a little practice the student can draw the threads in this way with his triangles, getting the proper slant and the angle spacing by eye, without the necessity of measuring; he should practice with this end in view, for threads occur so frequently on drawings that the draftsman must be able to draw them rapidly.

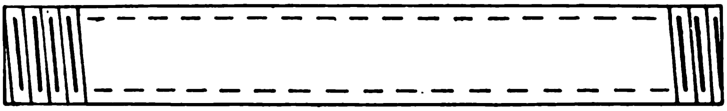

Fig. 28.

Notice should be taken of the fact that if the page be held so that the center lines of the screws in Figs. 25 and 26 are vertical, the lines which represent the threads slant downward from right to left. If the thread is left-handed the lines slant from left to right, as in Fig. 27.

In case of a long screw a few threads may be represented at each end and dotted lines carried the rest of the way, as in Fig. 28.

On any drawing of a screw which is intended for a working drawing, the pitch of the thread, or more commonly the number of threads for an inch of length should be specified; when the thread be standard, it is not always necessary to specify. Even in that case it is well to state the fact that the thread is standard. In giving the number of threads per inch it may be abbreviated, thus 12 THDS, or 12 TH. Examples of this will occur in what follows.

Threaded Holes and Invisible Threads. Fig. 29 shows a piece with a threaded hole in it. The hole is represented in the side view by the four parallel dotted lines. The distance apart of the two outer lines is equal to the diameter of the piece which is to be screwed into the hole. The inner lines are at a distance from the outer approximately equal to the depth of the thread. In the plan view of the piece (that is, the view looking at the end of the hole) the hole is shown by a full circle of a diameter equal to the distance apart of the inner dotted lines of the other view, and around this full circle a dotted circle whose diameter is equal to the diameter of the bolt; or, in other words, equal to the distance apart of the outer dotted straight lines. The dimension might be given on either view. In the figure it is given on the side view. In giving the diameter of a threaded hole, the diameter of the piece which is to be screwed into the hole is always given. In Fig. 29, the number of threads per inch is not stated, and in this case it would be understood to be standard. Fig. 30 shows another way of dimensioning a tapped hole, which is satisfactory and convenient.

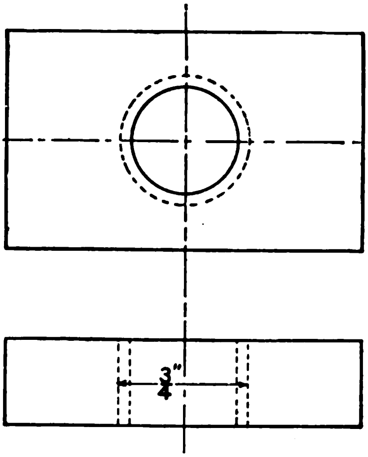

Fig. 29.

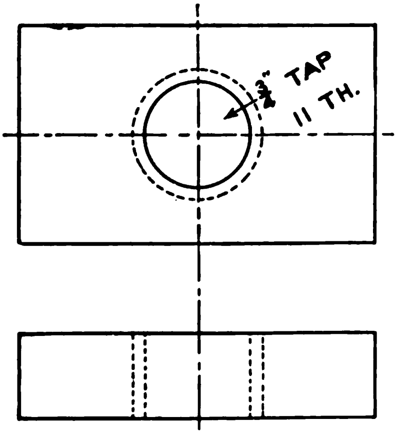

Fig. 30.

Fig. 31 shows the side view of the same piece as Fig. 29, with a part of the screw inserted in the hole. Attention is called to the fact that where the screw is hidden as it goes through the hole the thread is not shown, the parallel dotted lines representing the thread in the same manner as when the hole had no screw in it. Another point to be noted is that the cross-hatching of the broken ends for wrought iron is similar to the representation of the screw thread and one must learn to judge when the light and heavy lines mean a thread and when they are cross-hatching.

Threads in Sectional Pieces. Figs. 32, 33 and 34 illustrate the common method of representing threads when they occur on pieces which are drawn in cross-section. Fig. 32 is the same piece as Fig. 29, shown cross-sectioned. The front half of the piece is supposed to be removed and we are looking at the back half. Now the thread on the back side of a screw slants the opposite way from what it does on the front side, and of course the same is true of the thread in a tapped hole. Consequently, since it is the back side of the hole which is seen, the slant of the lines which represent the thread is opposite to the direction they would have were we looking at the front side of the screw which goes into the hole. We have just learned that for a right-handed thread on a screw the lines slant downward from right to left, and therefore for a right-handed thread seen on the back side of a tapped hole, the lines will slant downward from left to right. In other words, for a right-handed thread in a hole which comes in a cross-section, the lines slant the same as they would on the front of a left-hand thread on a bolt; and for a left-hand thread in a sectioned hole, he slant is the same as for a right-hand thread on a bolt.

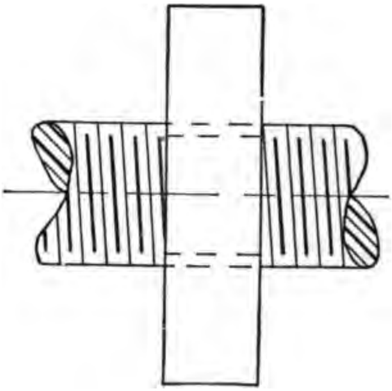

Fig. 31.

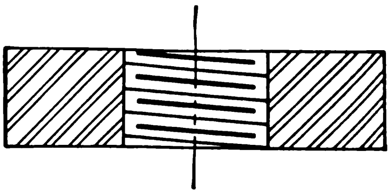

Fig. 32.

Fig. 33 is a piece which has a smooth hole through it and a thread on the outside. Here the entire thread is invisible, except at the contour of the cylinder, and must be indicated by the notches. These are drawn by spacing off the distance which is used for the pitch and from the points thus found drawing lines with the triangle which make an angle of 60 degrees with the axis of the cylinder. For a single thread the notches on one side have their outer points opposite the inner points of the notches on the other side. For a double thread the notches are directly opposite each other.

Fig. 34 shows two ways of quarter-sectioning a threaded piece, the only difference being that on one the contour of the sectional part is drawn a straight line, while on the other the contour is notched. Either one may be used. The straight contour can, of course, be drawn much more quickly and in places where there is no danger of sacrificing clearness it should be used for that reason. If the drawing is somewhat complicated, so that without the notches it might not be quite clear that the piece was threaded, the notches should be used.

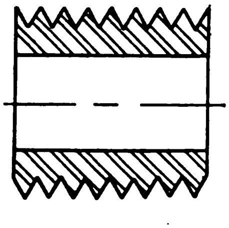

Fig. 33.

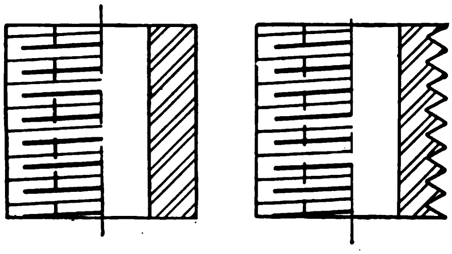

Fig. 34.

As has already been suggested, the student will doubtless find many other customs in the matter of drawing threads which are quite as good as the above. These have been given as ones which are common, and easily drawn. As a matter of convenience the following tables are given, which show the number of threads per inch on some of the most common sizes of bolts, according to the standard adopted by the United States Government, and the Whitworth or English standard.

UNITED STATES STANDARD SCREW THREADS.

Diameter of Bolt.	Threads per Inch.	Diameter of Bolt.	Threads per Inch.	Diameter of Bolt.	Threads per Inch.
$\frac{1}{4}$	20	$\frac{5}{8}$	11	$1\frac{3}{8}$	6
$\frac{5}{16}$	18	$\frac{3}{4}$	10	$1\frac{1}{2}$	6
$\frac{3}{8}$	16	$\frac{7}{8}$	9	$1\frac{5}{8}$	$5\frac{1}{2}$
$\frac{7}{16}$	14	1	8	$1\frac{3}{4}$	5
$\frac{1}{2}$	13	$1\frac{1}{8}$	7	$1\frac{7}{8}$	5
$\frac{9}{16}$	12	$1\frac{1}{4}$	7	2	$4\frac{1}{2}$

WHITWORTH STANDARD SCREW THREADS.

Diameter of Bolt.	Threads per Inch.	Diameter of Bolt.	Threads per Inch.	Diameter of Bolt.	Threads per Inch.
$\frac{1}{4}$	20	$\frac{5}{8}$	11	$1\frac{3}{8}$	6
$\frac{5}{16}$	18	$\frac{3}{4}$	10	$1\frac{1}{2}$	6
$\frac{3}{8}$	16	$\frac{7}{8}$	9	$1\frac{5}{8}$	5
$\frac{7}{16}$	14	1	8	$1\frac{3}{4}$	5
$\frac{1}{2}$	12	$1\frac{1}{8}$	7	$1\frac{7}{8}$	$4\frac{1}{2}$
$\frac{9}{16}$	12	$1\frac{1}{4}$	7	2	$4\frac{1}{2}$

Bolts and Nuts. Among the most common pieces of machinery are bolts and nuts, and the draftsman has frequent occasion to draw them. Fig. 35 is a conventional drawing of a $\frac{1}{2}$-inch bolt with a hexagonal head and nut. This figure shows the dimensions necessary to be given in order that a workman shall be able to make the bolt from the drawing.

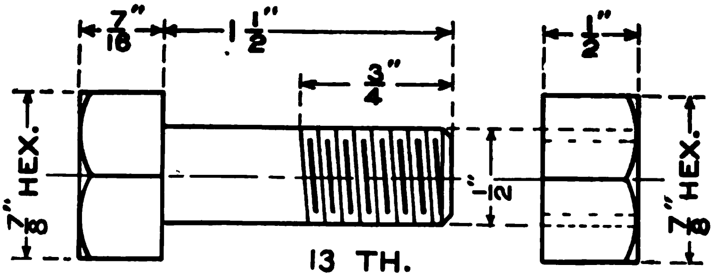

Fig. 35.

Beginning with the head of the bolt, let us study the various parts of this drawing in detail. The head is a hexagonal prism the end of which has been chamfered. We might expect that two views of the head would be necessary to completely define its shape, but the letters HEX printed after the dimension for the diameter of the head indicates that it is hexagonal. In like manner, if the head were square the letters SQ would be placed after the dimension. If two views were drawn, they would appear as in Fig. 36 The head is drawn as if the tool which cut the chamfer, cut off just the corners of the top, so as to make the top a circle tangent to the sides of the hexagon at B, E. G, etc.; the parts BCE, EFG, etc.. being portions of a cone or sphere according to the manner of chamfering. The curves ABC and CEF are tangent to the line

GK in the side view, and the lines AJ, CD, and FH are all equal in length. The curves ABC and CEF are properly the lines of intersection of a cone or sphere, as the case may be, with the hexagonal prism, but a convenient and sufficiently accurate way of drawing them is by arcs of circles with the center on the line HJ, half way between HD and DJ, as indicated. The chamfer is represented in the end view by a circle inscribed in the hexagon.

It will be noticed that in Fig. 35 that view of the head is given which shows two faces of the prism, so that the shortest dimension of the hexagon is given. That is, the view is taken in the direction of the arrow L, Fig. 36, instead of in the direction of the arrow M.

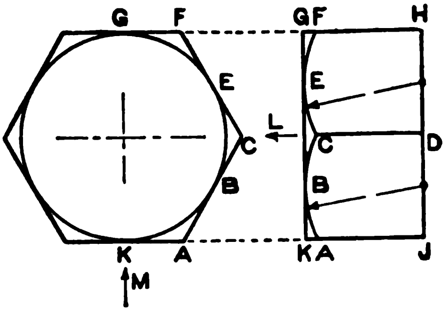

Fig. 36.

This rule should be followed on all detail drawings. The case when it is desirable to give a view in the direction of the arrow M will be discussed later.

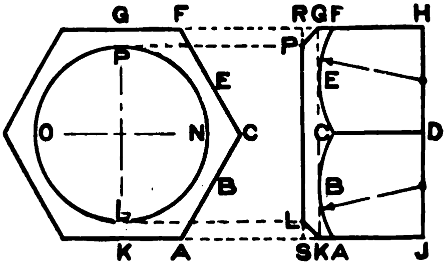

Fig. 37.

Sometimes it is desired to represent the chamfer as being greater, as in Fig. 37. To do this, draw the end view of the hexagon and inside it, of a diameter as much smaller as desired, draw the circle PNLO. Next draw the side view of the hexagonal prism as if there were no chamfer, as shown at the right (partly in dotted lines). Then from P and L, the upper and lower points of the circle in the other view, draw lines perpendicular to RS and meeting it at P and L. From P and L draw PG and LK, either at an angle of 45 degrees or 30 degrees (the latter being preferable) with RS, and meeting the lines RH and SJ at G and K. Join G and K by a construction line GK (shown dotted but not to be left in the finished drawing). Draw the arcs ABC and CEF with center on line HJ as shown, and tangent to GK.

Fig. 38 shows the proper way of representing the head which was shown in Fig. 36 if the view is taken in the direction of the arrow M. The dotted construction lines show how the widths are obtained. Fig. 39 shows the corresponding view of the head shown in Fig. 37. The radius with which the middle arc representing the chamfer is drawn in these two figures is apparent. Various rules are given for finding a radius for small arcs, but they can be found near enough by trial, after a little experience. The line TV, Fig. 39, to which the tops of the arcs are tangent, is drawn parallel to RS and at a distance from it equal to RG in Fig. 37.

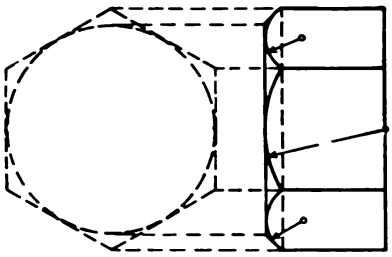

Fig. 38.

The nut, Fig. 35, is drawn in exactly the same way as the head, so that what has just been said will apply equally well to the nut. The hole in the nut is indicated by the four parallel dotted lines as explained for Fig. 29.

The shank of the bolt is represented with the thread upon it as explained above for conventional threads. The point is drawn chamfered a little in the figure, so that it appears as the frustum of a cone. Bolts often have round points, in which case they would be shown as in Fig. 40. The lines which represent the thread should not cross the line which is drawn square across the bolt to indicate where the chamfer or the rounding of the point begins.

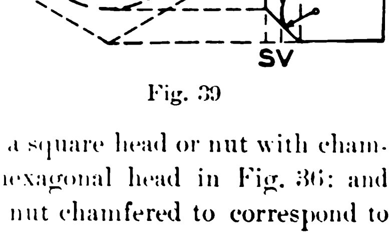

Fig. 39

Fig. 41 shows three views of a square head or nut with chamfer corresponding to that on the hexagonal head in Fig. 36: and Fig. 42 shows the square head or nut chamfered to correspond to

Fig. 37. Referring first to Fig. 41 the arc on the side view which shows the short diameter of the nut is drawn with a radius A, equal to two and one-quarter times the diameter of the bolt on which the head or nut belongs. The arcs on the other side view are drawn with a radius B, equal to one-half of A. The lines EF are drawn from points E tangent to the arcs, and it will be found that the points of tangency will come almost at the points where the arcs cut the lines CD. Points E are found by projecting from the plan view as indicated by the dotted lines. In Fig. 42, the construction is similar. The points N are first found by projecting from the top and bottom of the circle in the plan view; then the lines NL are drawn making angles of 30 degrees with line NN. (The proportions for the radii which are given, hold good only when the angle of 30 degrees is used). Next draw the construction line LL and draw the arc tangent to it with a radius A equal to two and one-quarter times the diameter of the bolt, the same as in Fig. 41. To draw the chamfer in the other side view, draw the construction line parallel to and at a distance from CC equal to the distance LL from NN and draw the arcs

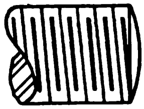

Fig. 40.

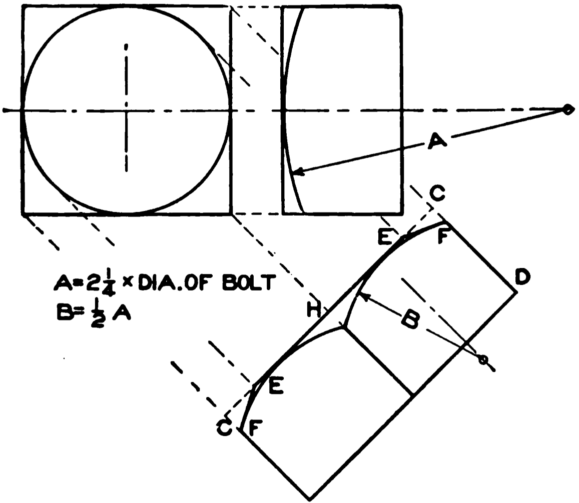

Fig. 41.

tangent to this line with radius B equal to one-half of A. The lines EF are then drawn as explained for Fig. 41.

Referring again to Fig. 35, the dimension which shows the length of the bolt under the head should be given to the extreme point of the bolt, as should also the dimension which shows how much of the bolt is threaded.

Most of the bolts in common use are made of standard sizes, that is, for a certain diameter of bolt there is a corresponding standard diameter and thickness for the head and the nut, and a standard number of threads per inch, so that if the bolt which the draftsman wishes to use has these standard dimensions they may be omitted from the drawing and a note made that the bolt is standard. Then the only dimensions necessary to be given are the diameter, the length under the head, and the length of the threaded part.

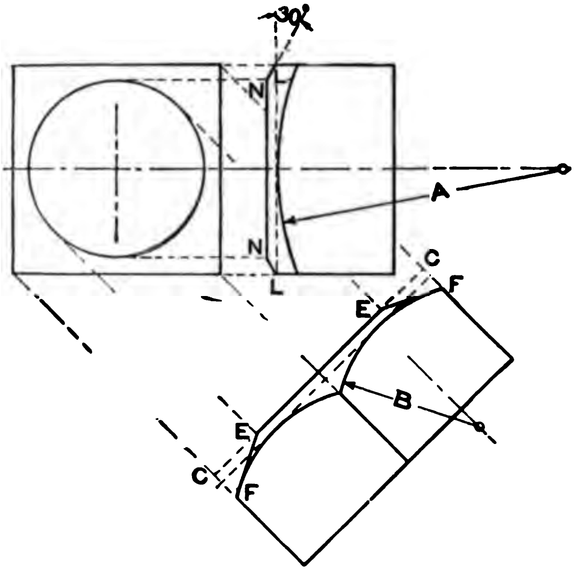

Fig. 42.

The following tables give the United States standard sizes of square and hexagonal heads and nuts for bolts. The columns headed "Width of Nut" and "Width of Head" give the shortest dimension of the square or hexagon, that is, the diameter of the inscribed circle. The standard number of threads per inch can be found from the table already given.

SQUARE BOLT HEADS. U. S. STANDARD (Franklin Institute).

Dia. of Bolt.	Width of Head.	Thickness of Head.	Dia of Bolt.	Width of Head.	Thickness af Head.
1/4	1/2	1/4	1	1 5/8	13/16
5/16	19/32	19/64	1 1/8	1 13/16	29/64
3/8	11/16	11/32	1 1/4	2	1
7/16	25/32	25/64	1 3/8	2 3/16	1 3/32
1/2	7/8	7/16	1 1/2	2 3/8	1 3/16
9/16	31/32	31/64	1 5/8	2 9/16	1 9/32
5/8	1 1/16	17/32	1 3/4	2 3/4	1 3/8
3/4	1 1/4	5/8	1 7/8	2 15/16	1 15/32
7/8	1 7/16	23/32	2	3 1/8	1 9/16

HEXAGON BOLT HEADS. U. S. STANDARD (Franklin Institute).

Dia. of Bolt.	Width of Head.	Thickness of Head.	Dia. of Bolt.	Width of Head.	Thickness of Head.
1/4	1/2	1/4	1	1 5/8	13/16
5/16	19/32	19/64	1 1/8	1 13/16	29/64
3/8	11/16	11/32	1 1/4	2	1
7/16	25/32	25/64	1 3/8	2 3/16	1 3/32
1/2	7/8	7/16	1 1/2	2 3/8	1 3/16
9/16	31/32	31/64	1 5/8	2 9/16	1 9/32
5/8	1 1/16	17/32	1 3/4	2 3/4	1 3/8
3/4	1 1/4	5/8	1 7/8	2 15/16	1 15/32
7/8	1 7/16	23/32	2	3 1/8	1 9/16

SQUARE AND HEXAGON NUTS. U. S. STANDARD (Franklin Institute).

Dia. of Bolt.	Width of of Nut.	Thickness of Nut.	Dia. of Bolt.	Width of Nut.	Thickness of Nut.
1/4	1/2	1/4	1	1 5/8	1
5/16	19/32	5/16	1 1/8	1 13/16	1 1/8
3/8	11/16	3/8	1 1/4	2	1 1/4
7/16	25/32	7/16	1 3/8	2 3/16	1 3/8
1/2	7/8	1/2	1 1/2	2 3/8	1 1/2
9/16	31/32	9/16	1 5/8	2 9/16	1 5/8
5/8	1 1/16	5/8	1 3/4	2 3/4	1 3/4
3/4	1 1/4	3/4	1 7/8	2 15/16	1 7/8
7/8	1 7/16	7/8	2	3 1/8	2

Pipes and Pipe Threads. The various kinds of pipe in common use are made to standard sizes, and as the draftsman very often comes in contact with piping we will consider it briefly. The kinds most often used are wrought-iron or steel pipe, brass pipe made to the size of wrought-iron pipe, and cast-iron pipe. The cast-iron pipe is made of different weights and form, according to the purpose for which it is to be used. Standard weight iron pipe is rated by its nominal inside diameter, although the actual diameter does not in most cases quite agree with the nominal diameter. A ¼-inch pipe is a pipe, the hole in which is supposed to be ¼ inch in diameter, but if carefully measured it will be found to be a few hundredths of an inch larger.

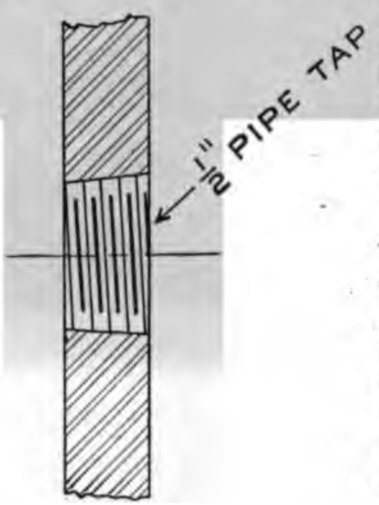

Fig. 43.

The threads on pipes and pipe fittings are also made to standard; taps and dies are made for various sizes of pipe. These taps and dies are spoken of or described by stating the size of the pipe for which they are intended For example, a ¼-inch pipe-tap is a tap of the proper size, shape, and number of threads per inch to cut the thread in a hole to receive a ¼-inch pipe. Threaded holes are made tapering for pipes, the standard taper being ¾ inch per foot, that is, the diameter of the hole decreases at the rate of ¾ inch per foot. In representing a hole which is threaded with a pipe tap, the hole is drawn of a diameter at its larger end about equal to the outside diameter of the pipe which is to be screwed into it, and is drawn tapering. It is well to make the taper considerably greater than the actual taper, so that the person looking at the drawing may see at a glance that the hole is for a pipe.

The thread is indicated in one of the conventional ways previously explained, but the number of threads per inch and the diameter of the hole need not be given; instead, a note is made

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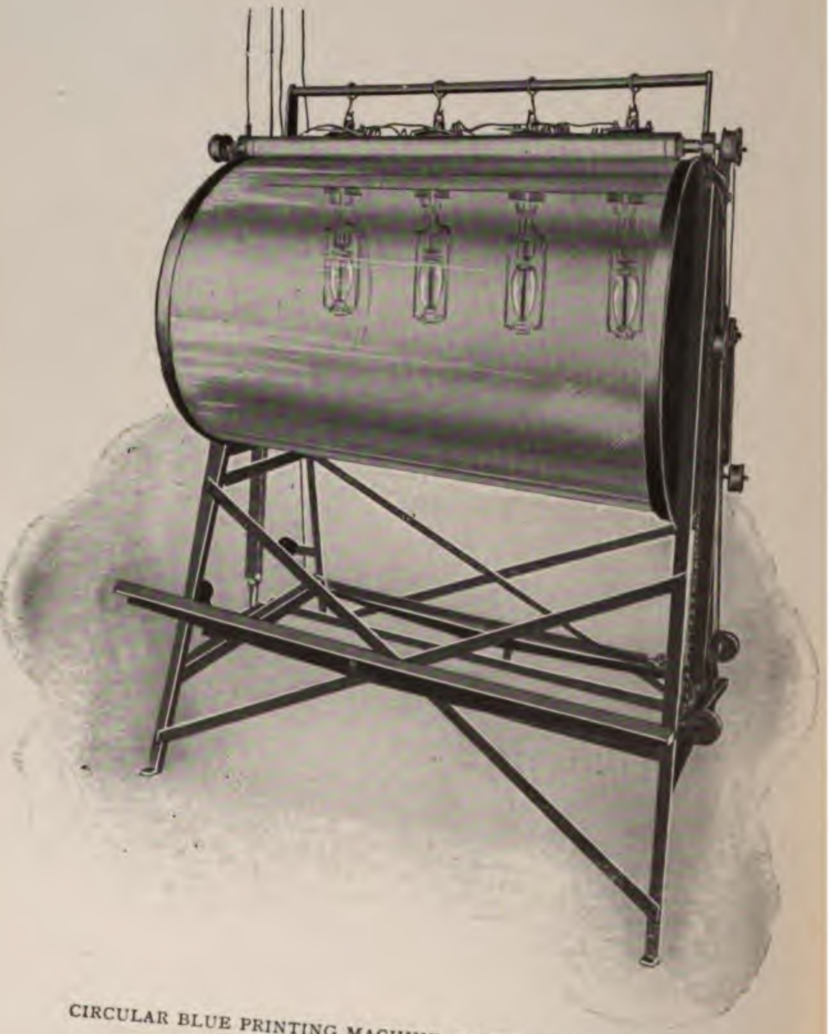

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that the hole is tapped for a certain size pipe. Fig. 43 illustrates this.

The following tables of standards for wrought-iron pipe may be found convenient:

STANDARD SIZES OF WROUGHT IRON PIPE.

Nominal Size.	⅛	¼	⅜	½	¾	1	1¼	1½	2
Actual Inside Diameter.	.27	.364	.494	.623	.824	1.048	1.38	1.610	2.067
Outside Diameter.	.405	.54	.675	.84	1.05	1.315	1.66	1.90	2.375
Nominal Size.	2½	3	3½	4	4½	5	6	7	8
Actual Inside Diameter.	2.468	3.067	3.548	4.026	4.508	5.045	6.065	7.023	7.982
Outside Diameter.	2.875	3.50	4.00	4.50	5.00	5.563	6.625	7.625	8.625

STANDARD THREADS FOR WROUGHT IRON PIPE.

Nominal Size of Pipe.	⅛	¼	⅜	½	¾	1	1¼	1½	2
Threads per Inch.	27	18	18	14	14	11½	11½	11½	11½
Nominal Size of Pipe.	2½	3	3½	4	4½	5	6	7	8
Threads per Inch.	8	8	8	8	8	8	8	8	8

Scale Drawings. When the object which is to be drawn is not so large but that it can be easily actual size, or full size as it is called, on a sheet of paper which is of convenient dimensions, it is well, usually, to draw the piece full size. In most cases, however, the machine, or the building, or whatever is to be drawn is so large that it would be impossible to draw it full size. Then the drawing is made to some reduced scale, that is, all the dimensions are drawn smaller than the actual dimensions of the object itself; all dimensions being reduced in the same proportion. For example, if a piece is to be drawn half size, the distance from one point to another on the drawing would be one-half what it is on the piece itself; if the drawing is one-fourth size, the distance on the drawing would be one-fourth what it is on the piece itself, and so on. In dimensioning such a drawing the dimension which is written on the drawing is the *actual dimension* of the piece, and not the distance which is measured on the drawing. This fact must be very clearly understood by the student.

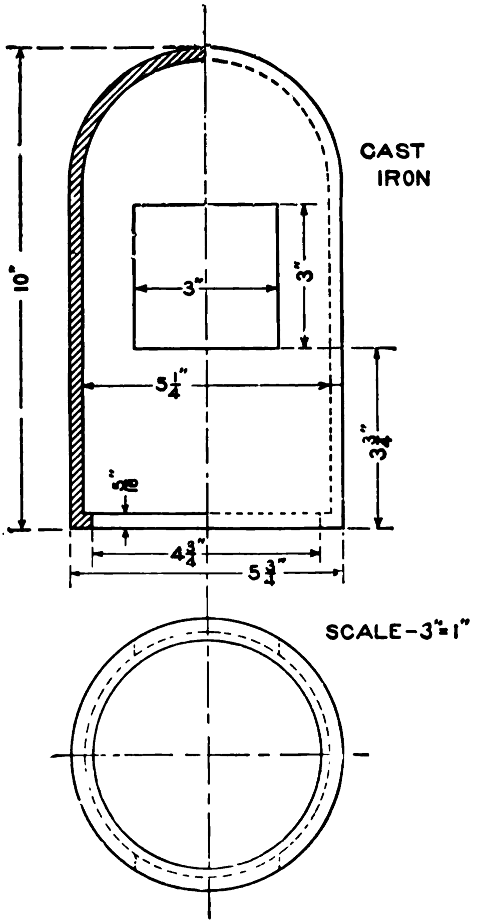


Fig. 44.

The common method of reducing all the dimensions in the same proportion is to choose a certain distance and let that distance represent one foot, this distance is then divided into twelve parts and each one of these parts represents an inch; then if half and quarter inches are required these twelfths are subdivided into halves, quarters, etc., until the subdivisions become so small that they cannot be used. We now have a scale which represents the common foot rule with its subdivisions into inches and fractions; but our new foot is smaller than the ordinary distance which we call a foot, and of course its subdivisions are proportionately smaller. When we make a measurement on the drawing we make it with our reduced foot rule and when we make a measurement on the machine itself we make it with the common foot rule.

Draftsmen's scales can be bought which have different distances thus divided, so that if the draftsman wishes to draw a piece one-fourth size he looks over his scale until he finds a distance of three inches (which is of course one-fourth of a foot) divided as explained above, and he uses this to measure with on his drawing. His drawing would then be made to a scale of three inches to the foot. In the same way, if he wishes to make his drawing one-twelfth size he finds on his scale one inch divided into twelfths and fractions of twelfths and uses this as his standard of measurement; if he wishes to make his drawing one forty-eighth size he uses a quarter inch with its subdivisions. Sometimes if the piece to be drawn is very small, the drawing is made at an enlarged scale, such as twice size, three times size, etc.

The mistake of choosing the wrong distance to use on a scale is often made. For example, if he wishes to draw a piece $\frac{1}{4}$ size, he will look over his scale for a place marked $\frac{1}{4}$, and use this for his standard for $\frac{1}{4}$ size, which is wrong. The figure on the scale indicates the distance which is divided up to represent one foot, so that the part of the scale which has $\frac{1}{4}$ marked on it means that $\frac{1}{4}$ of an inch is divided up into twelfths, or in other words, if a drawing is made according to that scale it will be $\frac{1}{48}$th size.

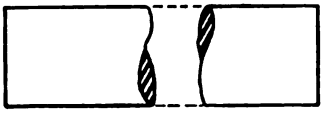


Fig. 45.

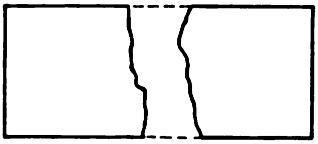


Fig. 46.

Every drawing which is made at any other scale than full size should have the scale marked on it plainly.

Fig. 44 shows a piece drawn to a scale of 3 inches per foot, that is, $\frac{1}{4}$ size.

Long Pieces. A piece which is very long in proportion to its diameter or width is often difficult to draw complete, especially if there is much detail to any part of it, for if the scale is made so small that the length will go on a sheet of paper of convenient size the small part is so reduced that it is very small. If such a piece is plain the whole or part of its length, a portion of the plain part may be broken out on the drawing thus shortening the drawing of the piece so that a larger scale may be used. Of course in giving the dimension for the length, the *actual* length must be given. Fig. 45 shows a round piece thus broken out and Fig. 46 a **rectangular piece.**

It is a good idea to connect by dotted lines the two parts thus broken, although this is not essential.

"Turning Up" a Section. Sometimes a second view of a piece may be avoided by drawing on the first view a partial view showing the shape of the cross-section at the place where drawn. This partial view or "turned-up section" may be drawn in either full or dotted lines and should be cross hatched. If it comes where there are other lines of the original view, as is usually the case, the original lines would be drawn in regardless of the fact that they conflicted with the auxiliary view. Fig. 47 is an illustration.

In General. A working drawing will usually belong to one of the three following classes: *first*, a design of an entirely new machine; *second*, a drawing of a machine which is already built; *third*, a drawing of a new part to fit a machine which is already built, or a drawing of an old machine remodelled.

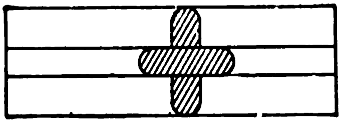


Fig. 47.

In order to design a new machine or a part of a machine, the draftsman must understand the principles of drawing and must also have a clear understanding of the work which the machine is to perform, and must know something of the principles of machine design and the strength of materials. A study of the general manner of proceeding with the drawing, when these things are known, will come later in this course. The draftsman may make a drawing of a machine which is already built, even if he has no understanding of the working of the machine, although under such conditions he works at a great disadvantage. In any case, he must know the principles of drawing.

If the student has learned thoroughly what has preceded in this course, he should be ready to take up the drawing from a machine, and we will now consider the general system to be followed in making such a drawing.

Sketches. In most cases it would be inconvenient for the draftsman to take his drawing board and instruments to the machine and make his careful drawing with the machine close at hand; preferably, he makes what are called sketches, carries his sketches to the drafting room and makes his drawing from them. In making the sketches, each piece of the machine should be taken separately and a complete working drawing made of it, the only difference between these sketches and the finished drawing being that they are made largely without the use of instruments, triangles, etc.; that is, they are made free hand. The experienced draftsman will draw some lines and circles free hand, and use his instruments on some, according as he may think that he will save time by doing the one or the other; but it is well for the beginner to gain practice by making the sketches, almost wholly free hand, except large circles, and long lines.

The sketches should be neat and perfectly clear, so that if they are laid aside for a long time they can be clearly understood without depending at all upon memory. There is a strong tendency for the beginner to make his sketches hurriedly, thinking that when he comes to finish his drawing he can supply the details from memory. This is a bad plan and will lead to many mistakes. The sketches must be so clear and complete that anyone can read them who has never seen the machine. No attempt need be made to draw them to scale, but **all dimensions**, carefully measured from the machine, should be placed on the sketch.

After every piece of the machine has been thus sketched separately, it is well to make a rough, general sketch of the whole machine, to show how the various pieces fit together, a few of the most important over-all dimensions, distances between centers, etc.

All sketching should be done as rapidly as possible without sacrificing clearness. Before starting to sketch a piece, the draftsman must decide what views are necessary to describe the piece clearly. All sketches should be made large to avoid confusion.

Detail Drawing. After the sketches are made, the next step is the making of the pencil drawing from the sketches, accurately to scale. The size of the plate on which the drawing is to be made is usually fixed by some standard. Where many drawings are made and kept in an office, it is desirable to keep the plates of uniform size, as far as possible. It is good practice to have two or three standard sizes of plates, one for small drawings, one for ordinary-sized work, and one for large drawings; then, whenever a drawing is made, make it on one of these standard plates.

Assuming, then, that we have our paper stretched on the drawing board and the plate laid out, the next step will be to arrange the drawings of the various pieces on the plate so that there will be room for all and so that they may be properly placed with relation to each other. It may happen that there will not be room on one plate for all the pieces, but that two or more plates will be required. When the parts must be thus arranged on different plates, an effort should be made to keep on the same plate those parts which belong together. For example, if we were drawing a lathe, the details of the parts of the head stock might form one plate, the apron another, and so on.

In locating the various pieces on a plate, they should be placed as nearly as possible in the same relative position to each other that they bear in the machine, except that they are separated. For example: if a nut belongs on the end of a screw, it is desirable to draw it on the same center line with the screw and at the end where it belongs. If a piece is vertical in the machine it should be vertical on the plate, and if horizontal in the machine, it should be horizontal on the plate.

The approximate location of the pieces on the plate may be asily decided by taking a small sheet of paper of about the same proportion as the plate, but perhaps one-fourth or one-half size, and sketching on it roughly the outline of the various pieces. The arranging of the plate should not be allowed to take much time, but should be done as rapidly as possible. After the location of each view of each piece is determined, the pencil drawing should begin (to scale) with one of the principal pieces. In almost all cases a center line is first drawn. It is better to carry along all the views of a piece at once, instead of completing one view at a time. The piece started should have all its views finished and completely dimensioned before another piece is begun; exceptions to this are sometimes necessary for special reasons. The lines should be drawn accurately, but no attempt need be made to obtain finish; that is, in order to save time, the lines may be run past the point where they should properly stop, etc. Nothing should be omitted, however.

Each plate of details should have a title, stating of what machine it is a drawing, and, if there are several plates, it is well to state also of what part of the machine the plate in question is a drawing. It is also a good idea to print its name beside each of the principal pieces.

Tracing. Having finished the pencil drawing, the next step is the inking. In some offices the pencil drawing is made on a thin. tough paper, called board paper, and the inking is done over the pencil drawing, in the manner with which the student is already familiar. It is more common to do the inking on thin, transparent cloth, called tracing cloth, which is prepared for the purpose. This tracing cloth is made of various kinds, the kind in ordinary use being what is known as "dull back," that is, one side is finished and the other side is left dull. Either side may be used to draw upon, but most draftsmen prefer the dull side. If a drawing is to be traced it is a good plan to use a 3H or 4H pencil, so that the lines may be easily seen through the cloth.

The tracing cloth is stretched smoothly over the pencil drawing and a little powdered chalk rubbed over it with a dry cloth, to remove the slight amount of grease or oil from the surface and make it take the ink better. The dust must be carefully brushed or wiped off with a soft cloth, after the rubbing, or it will interfere with the inking.

The drawing is then made in ink on the tracing cloth, after the same general rules as for inking the paper, but care must be taken to draw the ink lines exactly over the pencil lines which are on the paper underneath, and which should be just heavy enough to be easily seen through the tracing cloth. The ink lines should be firm and fully as heavy as for ordinary work. In tracing, it is better to complete one view at a time, because if parts of several views are traced and the drawing left for a day or two, the cloth is liable to stretch and warp so that it will be difficult to complete the views and make the new lines fit those already drawn and at the same time conform to the pencil lines underneath. For this reason it is well, when possible, to complete a view before leaving the drawing for any length of time, although of course on views in which there is a good deal of work this cannot always be done. In this case the draftsman must manipulate his tracing cloth and instruments to make the lines fit as best he can. A skillful draftsman will have no trouble from this source, but the beginner may at first find difficulty.

Inking on tracing cloth will be found by the beginner to be quite different from inking on the paper to which he has been accustomed, and he will doubtless make many blots and think at first that it is hard to make a tracing. After a little practice, however, he will find that the tracing cloth is very satisfactory and that a good drawing can be made on it quite as easily as on paper.

The necessity for making erasures should be avoided, as far as possible, but when an erasure must be made a good ink rubber or typewriter eraser may be used. If the erased line is to have ink placed on it, such as a line crossing, it is better to use a soft rubber eraser. All moisture should be kept from the cloth.

Blue Printing. The tracing, of course, cannot be sent into the shop for the workmen to use, as it would soon become soiled and in time destroyed, so that it is necessary to have some cheap and rapid means of making copies from it. These copies are made by the process of blue printing in which the tracing is used in a manner similar to the use made of a negative in photography.

Almost all drafting rooms have a frame for the purpose of making blue prints. These frames are made in many styles, some simple, some elaborate. A simple and efficient form is a flat surface usually of wood, covered with padding of soft material, such as felting. To this is hinged the cover, which consists of a frame similar to a picture frame, in which is set a piece of clear glass. The whole is either mounted on a track or on some sort of a swinging arm, so that it may readily be run in and out of a window.

The print is made on paper prepared for the purpose by having one of its surfaces coated with chemicals which are sensitive to sunlight. This coated paper, or blue-print paper, as it is called, is laid on the padded surface of the frame with its coated side uppermost; the tracing laid over it right side up, and the glass pressed down firmly and fastened in place. Springs are frequently used to keep the paper, tracing, etc., against the glass With some frames it is more convenient to turn them over and remove the backs. In such cases the tracing is laid against the glass, face down; the coated paper is then placed on it with the coated side against the tracing cloth.

The sun is allowed to shine upon the drawing for a few minutes, then the blue-print paper is taken out and thoroughly washed in clean water for several minutes and hung up to dry.

If the paper has been recently prepared and the exposure properly timed, the coated surface of the paper will now be of a clear, deep blue color, except where it was covered by the ink lines, where it will be perfectly white.

The action has been this: Before the paper was exposed to the light the coating was of a pale yellow color, and if it had then been put in water the coating would have all washed off, leaving the paper white. In other words, before being exposed to the sunlight the coating was soluble. The light penetrated the transparent tracing cloth and acted upon the chemicals of the coating, changing their nature so that they became insoluble; that is, when put in water, the coating, instead of being washed off, merely turned blue. The light could not penetrate the ink with which the lines, figures, etc., were drawn, consequently the coating under these was not acted upon and it washed off when put in water, leaving a white copy of the ink drawing on a blue background. If running water cannot be used, the paper must be washed in a sufficient number of changes until the water is clear. It is a good plan to arrange a tank having an overflow, so that the water may remain at a depth of about 6 or 8 inches.

The length of time to which a print should be exposed to the light depends upon the quality and freshness of the paper, the chemicals used and the brightness of the light. Some paper is prepared so that an exposure of one minute, or even less, in bright sunlight, will give a good print and the time ranges from this to twenty minutes or more, according to the proportions of the various chemicals in the coating. If the full strength of the sunlight does not strike the paper, as, for instance, if clouds partly cover the sun, the time of exposure must be lengthened.

Assembly Drawing. We have followed through the process of making a detail drawing from the sketches to the blue print ready for the workmen. Such a detail drawing or set of drawings shows the form and size of each piece, but does not show how the pieces go together and gives no idea of the machine as a whole. Consequently, a general drawing or assembly drawing must be made, which will show these things. Usually two or more views are necessary, the number depending upon the complexity of the machine. Very often a cross-section through some part of the machine, chosen so as to give the best general idea with the least amount of work, will make the drawing clearer.

The number of dimensions required on an assembly drawing depends largely upon the kind of machine. It is usually best to give the important over-all dimensions and the distance between the principal center lines. Care must be taken that the over-all dimensions agree with the sum of the dimensions of the various details. For example, suppose three pieces are bolted together, the thickness of the pieces according to the detail drawing, being one inch, two inches, and five and one-half inches respectively; the sum of these three dimensions is eight and one-half inches and the dimensions from outside on the assembly drawing, if given at all, must agree with this. It is a good plan to add these over-all dimensions, as it serves as a check and relieves the mechanic of the necessity of adding fractions.

FORMULA FOR BLUE-PRINT SOLUTION.

Dissolve thoroughly and filter.

A.	Red Prussiate of potash	2⅛	ounces,
	Water	1	pint.
B.	Ammonio-Citrate of iron	4	ounces,
	Water	1	pint.

Use equal parts of A and B.

FORMULA FOR BLACK PRINTS

Negatives. White lines on blue ground; prepare the paper with

Ammonic-Citrate of iron	40 grains,
Water	1 ounce.

After printing wash in water.

Positives. Black lines on white ground; prepare the paper with:

Iron perchloride	616 grains,
Oxalic Acid	308 grains,
Water	14 ounces.

Develop in	Gallic Acid	1 ounce,
	Citric Acid	1 ounce,
	Alum	8 ounces.

Use 1¼ ounces of developer to one gallon of water. Paper is fully exposed when it has changed from yellow to white.

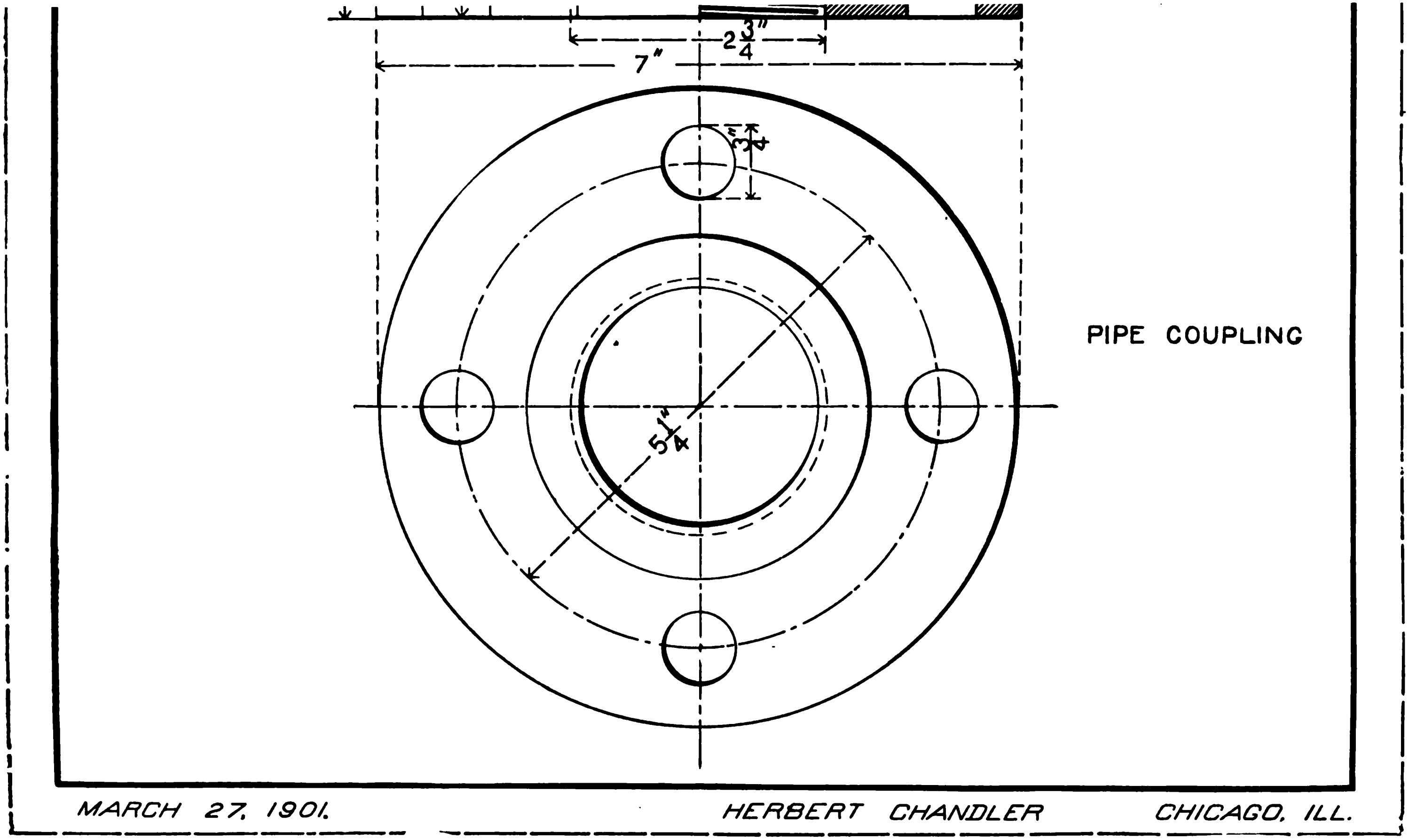
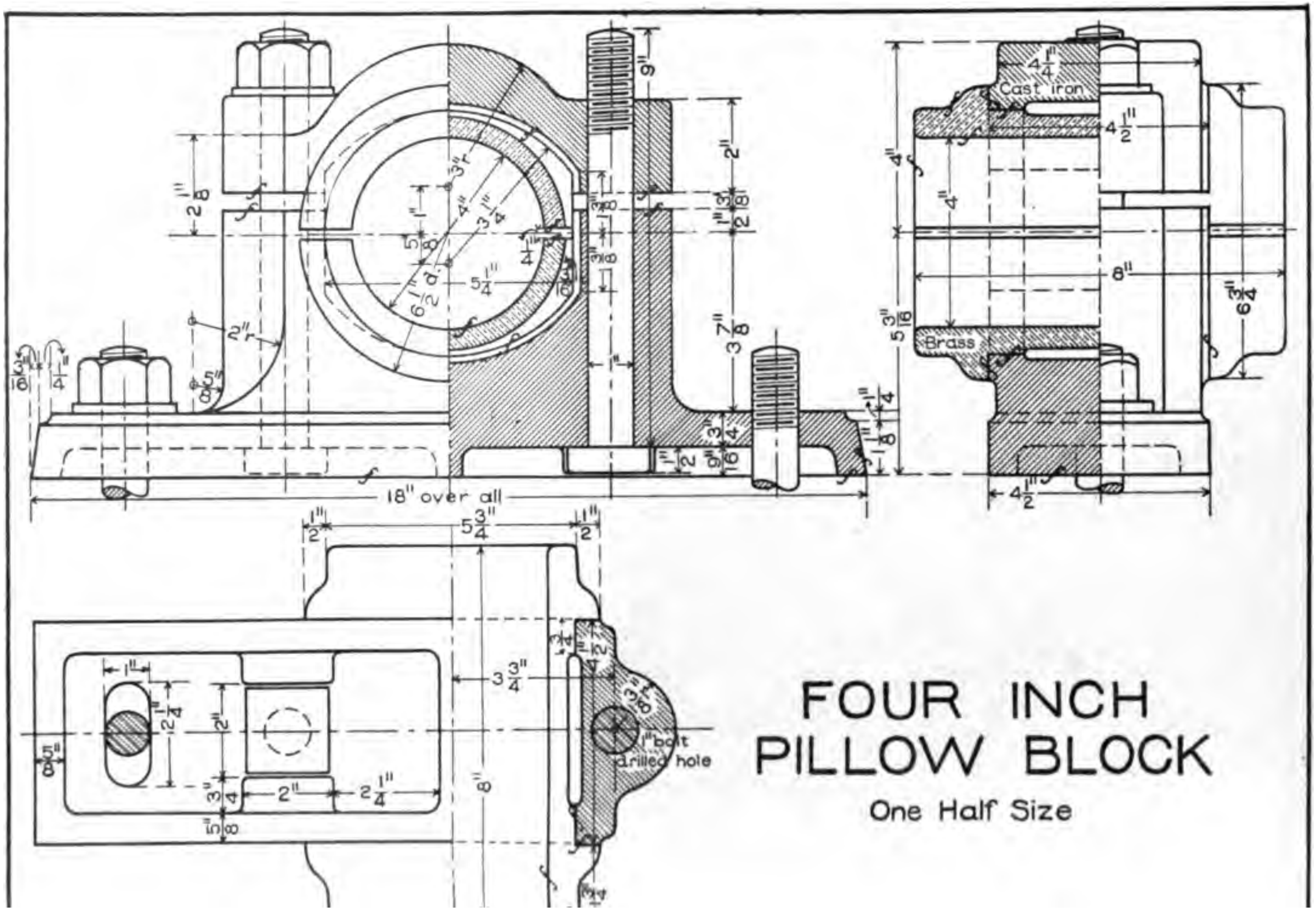

7"
$2\frac{3}{4}$"
$\frac{3}{4}$"
$5\frac{1}{4}$"
PIPE COUPLING
MARCH 27, 1901.
HERBERT CHANDLER
CHICAGO, ILL.

PLATE IX



FOUR INCH PILLOW BLOCK

One Half Size

PLATES.

PLATE VIII.

Pipe Coupling. The drawing represents one of a pair of cast-iron couplings used for connecting two lengths of pipe. It is threaded for a right-handed thread, but appears left-handed because the back part of the thread is visible in the section.

The vertical center line of the coupling is in the center of the plate; the center of the plan is $3\frac{7}{8}$ inches from the lower border and the bottom of the elevation $1\frac{7}{8}$ inches from the top border line. The elevation is made in half section, that is, the right-hand half. It is made by imagining that the front right quarter of the coupling is cut away by vertical planes. If the cutting plane passes through a hole or opening the cross-hatching is omitted. The dotted lines at the left of the hole show that it is threaded. The distance between these lines is $\frac{3}{32}$ inch, the depth of the thread. The threaded or tapped portion is shown in plan by the two circles, the dotted circle representing the outside and the full circle the inside or root of the thread.

The boss or hub adds to the strength and allows more threads. The shade lines should be placed on the drawing following the custom for shop drawings. The title "Pipe Coupling" should be placed as shown and made with letters $\frac{1}{4}$ inch high. The letters may be either vertical or inclined Gothic capitals.

PLATE IX.

Pillow Block. The drawings for this plate are three views—side, plan and end—of a 4 inch-pillow block. Each view is half in section. The drawing should be one-half size. Make the vertical center line of the side and plan views $4\frac{3}{4}$ inches from the left-hand border. The horizontal center line of the side view should be $2\frac{3}{8}$ inches from the top border line and the horizontal center line of the plan $2\frac{1}{4}$ inches from the bottom border line. Locate the vertical center line of the end view $2\frac{1}{4}$ inches from the right-hand border line; the horizontal center line will of course be a continuation of that of the side view. Note that the left-hand half of the plan represents what is seen by looking up from below. The cutting plane for the right-hand half passes horizontally through the center of the shaft.

The student should put on shade lines and finish marks; also the notes and dimensions. Make the letters of the title vertical Gothic capitals $\frac{3}{8}$ inch high.

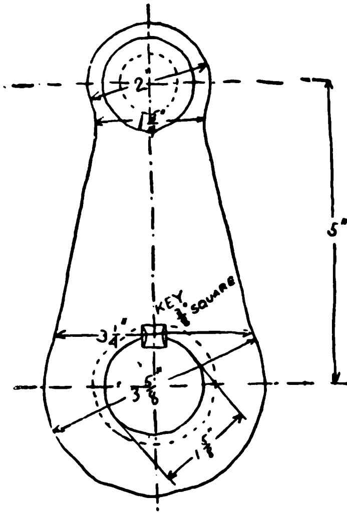


Fig. 48.

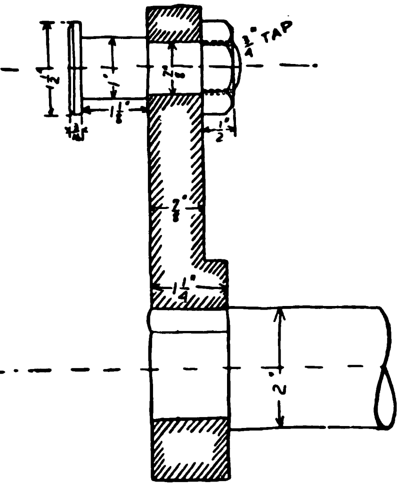


Fig. 49.

PLATE X.

Overhung Crank. The two drawings on this plate are to be made full size from the free-hand sketches Figs. 48 and 49. These are such as would be given the draftsman or such he would make for his own work. Place the two views so that they will look well on the plate. Put on shade lines and dimensions.

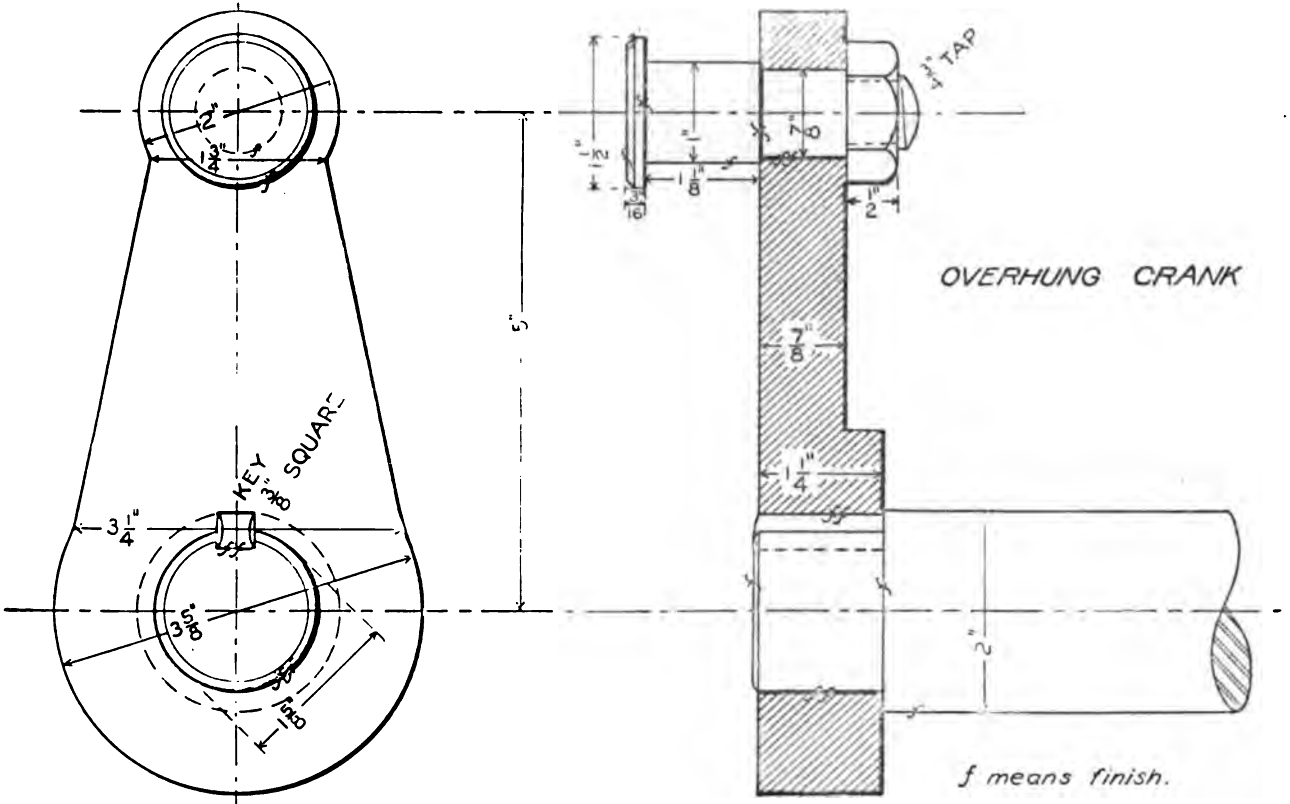
PLATE XI.

Cylinder Head. This plate consists of a plan view and a cross-section of the cylinder head of a small engine. The center line for the two views is drawn half way between the upper and lower border lines. Always allow sufficient space for dimensions.

The shade lines should be placed on the drawing, following the methods described for machine drawing. Locate the title and explanatory notes to make the plate appear well balanced.

PLATE XI A.

Blue Print. Make a tracing on tracing cloth and (optional) a blue print of one of these plates.



OVERHUNG CRANK

f means finish.

MAY 12, 1901.

HERBERT CHANDLER, CHICAGO, ILL.

THE NEW YORK
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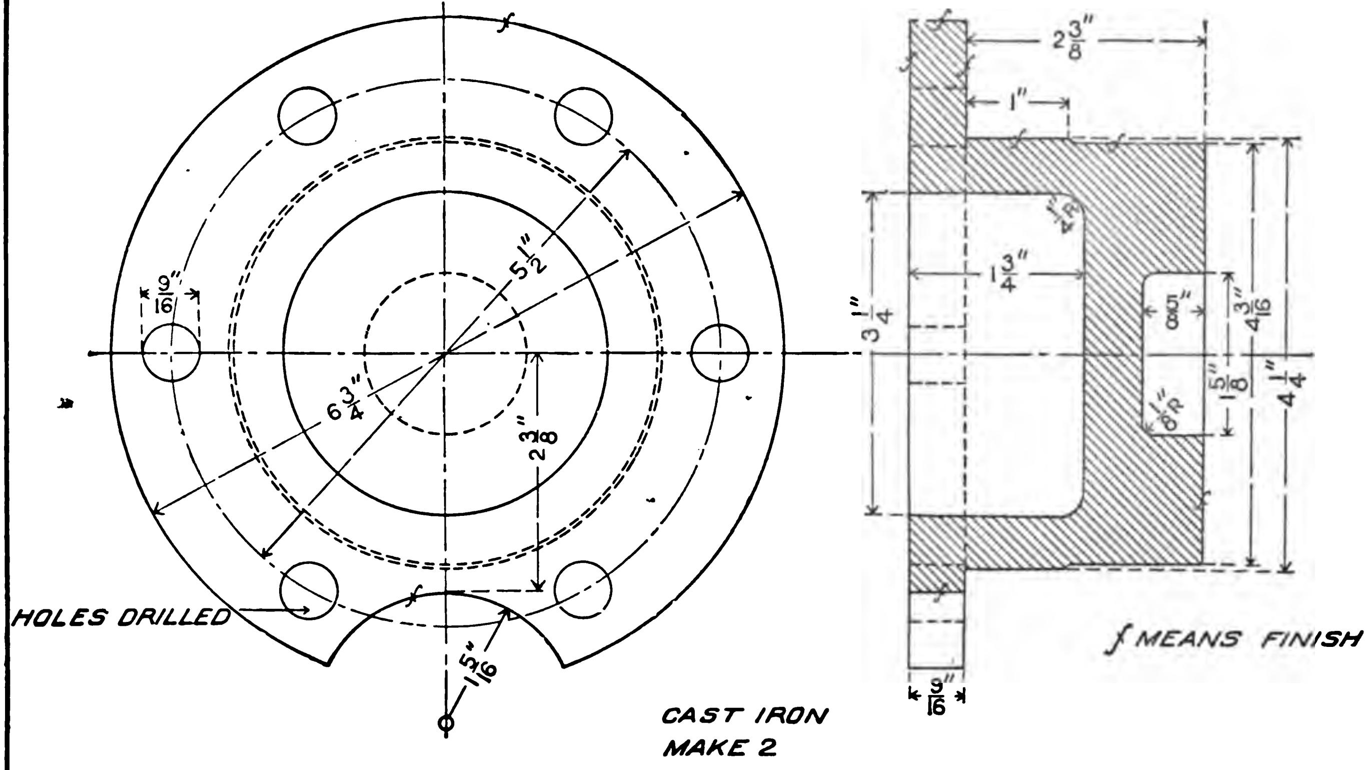
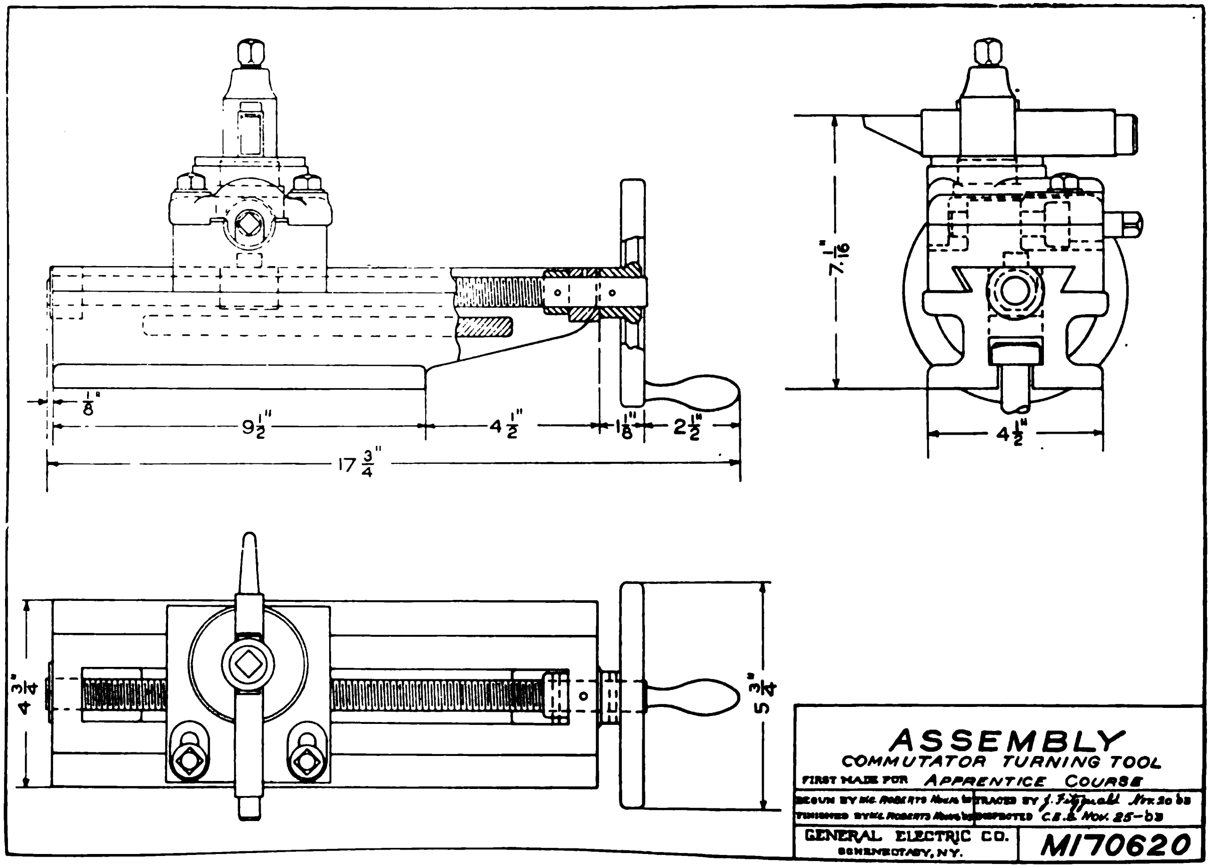
ASTOR, LENOX AND
TILDEN FOUNDATIONS

CYLINDER HEAD



MAY 20. 1901. HERBERT CHANDLER CHICAGO, ILL.



EXAMPLE OF SHOP DRAWING MADE IN DRAFTING ROOM OF THE GENERAL ELECTRIC COMPANY.

MECHANICAL DRAWING.

PART VI.

WORKING SHOP DRAWINGS.

In Parts I to IV, inclusive, the fundamental principles of Mechanical Drawing were explained and illustrated. The production of working drawings has also been discussed to some extent, and the usual characters and symbols explained and applied. The elementary work already outlined has been treated chiefly from the standpoint of correctness of line representation considered by itself, without a detailed study of the use to which the drawings so produced are to be applied.

Evidently this is the proper method, for the student should gain a thorough understanding of the principles which underlie line representation before attempting to apply them to any extended practical use. In all of this preceding work it is intended that the theoretical principles shall overshadow any incidental references made to practical application, however true and pertinent the latter may be for purposes of illustration. Hence, before taking up any advanced work, the student should fully realize the importance, in fact, the absolute necessity, of thoroughly understanding the fundamental principles which have been outlined in the books which have preceded Part VI.

At this point the student must realize that a lack of proper elementary and fundamental training will make him "go lame" at every point of his course, and probably prevent the attainment of proficiency which otherwise would naturally and almost instinctively come with advanced study. It is the thorough and ready knowledge, always at his fingers' ends, of *all* the principles of Mechanical Drawing, which makes the expert draftsman.

Plan and Scope of Advanced Work. It is now intended to throw an entirely different light on the matter, and view the subject of Mechanical Drawing from a purely practical standpoint; viz., that of Utility. It is assumed that the student understands and can use the principles which have been previously discussed.

If in a working shop drawing we choose to modify any of these theoretical principles, it will be because of increased value in *Utility* of the drawing. For example, we may desire to omit some portions of an elevation or plan or side view of a complicated casting, because certain details will thus be more clearly brought out. We may make a "zigzag" section to show construction which, by absolute fidelity to theoretical principle, would be confused, or hidden in a maze of dotted lines. We may find it convenient to place in some unoccupied corner of a drawing a layout which could not be in the least justified by any rule of projection. A multitude of transgressions like these occur on good drawings, and they are certainly justifiable from the standpoint of *Utility*, which is the true ultimate end sought for in a practical shop drawing.

These variations from the theoretical are not strictly conventionalities, because they are not classified or established, so far as we know, but are the spontaneous outgrowth, as the occasion demands, of the draftsman's purpose to make his drawing one of greatest *Utility*. He can, however, safely transgress a principle only when he thoroughly knows the principle; otherwise a blind deviation from the theoretical path will inevitably lead to difficulty.

All of the above is intended to impress the student with the idea that theoretical principles are his best, in fact, his only tools to work with; but they are not "self-hardening," like "mushet" steel; they are like the finest grade of tool steel, which must be tempered and ground and used with the best judgment of the operator, to secure the most satisfactory results.

Student Drawings. A student's early drawings are usually unsatisfactory, even to himself. Somehow they do not look like those seen in shops, and as a rule he is unable to see why this is so. Of course the difference is to some extent due to the experience of the professional draftsman. However, the superior results of the latter's work are attained largely through his systematic and workmanlike habits of execution. It should encourage the student in his early attempts to know that these essentials to the infusion of life and shop spirit into a drawing can be analyzed, outlined and grasped at the outset by earnest, intelligent effort, and really good workmanlike results obtained. To discuss, and if possible to impart these essentials of a working shop drawing to the student, is the purpose of the present book.

Essentials. The two chief essentials of a shop drawing, under which general heads a multitude of detail requirements can be summed up, are:

(1.) Absolutely complete and definite instructions from designer to workman.

(2.) Least possible cost in dollars and cents of production of the drawing measured by the draftsman's time.

It makes no difference how much we may attempt to disguise these two elements, the fact will still be apparent that "*complete instructions furnished for the least money*" is what the manufacturing shop is after, and what will be assumed as a basis for judgment as to highest commercial utility.

Completeness of Drawings. As to the first point, that of completeness and definiteness of instruction, there must be no question of degree. If the information which the drawing furnishes is positive and complete, the drawing is good. If doubt arises in the workman's mind as to what the designer intended by a certain line or dimension, or if the dimension be omitted, the drawing is bad. There is no middle ground. The instructions are either present or absent, and the drawing good or bad accordingly.

The workman of to-day is not permitted to assume dimensions or shape. It is his business to execute the draftsman's orders; it is, however, often his privilege to choose his own way of doing it, but further than this modern practice does not allow him to go. He is held as rigidly to the orders specified by the drawing as the locomotive engineer is held to his bit of tissue telegraphic order to proceed, without which he dare not enter the next block. The drawing is supreme; it is official; it must be plain, direct and all-sufficient. It is the draftsman's business to make it thus, and he is not a draftsman until he does.

This idea of positiveness must be thoroughly absorbed by the student. Positive action must be a habit which controls his every move, which marks every dimension he prints, which directs every line he draws. Every line must mean something, must have a definite reason for existence, must be necessary to illustrate the idea which he wishes to convey to the workman, and every line must be a definite measurable distance from every other line, so that its location is fixed beyond 'a doubt. Lines which mean nothing, and cannot be measured, have no place on the drawing; they only confuse it.

A good picture of a machine could scarcely be called to the same service as a good drawing of it. The picture might give us an excellent idea of the machine, but for the purpose of the actual construction the picture is useless, while the drawing is of positive value. This value exists simply because of, and in proportion to, the completeness of detail which it shows. Hence in making a shop drawing the picture idea is entirely subordinate to the idea of *Utility*, the latter in fact being the measure of its value.

There are certain classes of drawings—of which the Patent Office drawing is a good example—in the making of which the picture idea is predominant. Here the purpose is to illustrate mechanisms, not construct them; hence the function of the drawing is in no wise that of the working shop drawing, and as such does not fall within our discussion.

Cost of Producing Drawings. The second general element involved in producing shop drawings is their cost, as measured by the draftsman's time. It is somewhat subordinate to the first element, for the drawing must be a good one, judged by an absolute standard, whatever the time or cost necessary to produce it. Cost, however, is an important item, and cannot well be overlooked. It is inevitable that in any enterprise economy will ultimately be sought, whatever extravagance an imperative original demand may have permitted. This is as true in the production of drawings as in the case of manufactured articles of trade. Drafting-room labor is a relatively high-priced service, and the salary list easily assumes considerable proportions, so that wasteful excesses count up rapidly. One of the qualifications of proficiency invariably required for this department of shop organization is rapidity of execution. This is not as dependent upon personal traits as at first might be supposed. A man may so husband his time and direct his efforts that he will easily distance his neighbor of more rapid motion. The latter may have less ability to make his energies count, and lack of judgment as to when just enough, and no more than enough, energy has been expended on his drawings. From the standpoint of *Utility*, the function of a drawing is fulfilled when it has reached the stage that it *completely* instructs; more time spent in elaboration is wasted, and is an unnecessary and therefore extravagant expenditure. The student must fully realize this. In his earnestness to produce finished and complete work he must constantly strive to accomplish results in the least possible time. This does not mean careless haste; far from it. A complete shop drawing cannot be made by short cuts, but through a systematic building of line on line, dimension on dimension. This is in sharp contrast to a haphazard habit of developing a drawing, first a line here and then a figure there, with no definite purpose in mind, and no hint as to when the drawing is actually completed.

The one method constitutes the efficient draftsman who works easily, receives a high salary, and is worth it, because he wastes no time in unnecessary labor. The other marks his unfortunate brother, plodding laboriously far behind, receiving a small pittance per hour, and worth less, because he does uncalled-for labor, and loses his definiteness of purpose in a maze of unexplainable lines and figures.

A working shop drawing, commercially considered, may well be defined as being "*Complete instruction from designer to workman issued at minimum expense.*"

This definition should be memorized by the student, and constantly kept in mind while making a drawing. The preceding pages should be re-read with this in view until the full spirit is appreciated.

The maxim as given above, if faithfully adhered to without modification, answers nearly every question that can be raised as to the excellence of a drawing. It can be used as a standard of judgment, whatever system of lines or symbols may be in vogue. It permits a draftsman to adjust himself to the rules of any shop or drawing-room, and yet produce a good drawing and satisfy his employer.

A drawing which is cheaply produced and at the same time does perfectly that for which it was made, that is, convey complete instruction, is beyond commercial criticism.

Method of Procedure. As the general objects to be attained in a working shop drawing have now been presented, it is necessary to indicate in detail how the work may be properly accomplished. In order to do this, it is proposed to produce systematically a full set of working drawings of a familiar and comparatively simple machine. The methods used will be those of a designing detail draftsman, producing commercial work fit for shop use. In the progress of the work, from its beginning in the rough, though accurate, pencil layout, to the completion of the tracings and the order sheets, the same bold style, clearness, directness and businesslike spirit which the shop atmosphere and surroundings would naturally supply, will be emphasized, and so far as possible imparted to the student. It is expected that the student will follow the text closely and study the plates carefully, endeavoring to familiarize himself with every detail illustrated. The more closely he is able to apply himself in this respect the more will he be able to partake of the life and spirit which is intended to be conveyed, and without which the true character of the work can be but poorly developed.

Incidentally, several purposes will be fulfilled by this treatment.

Ability to read drawings quickly and intelligently is almost as important as making them, and it is expected that the study of the plates, with a view to thoroughly understanding every line, will develop proficiency in the art of reading drawings.

The discussion in the text, of not only the form of the machine parts themselves, but also the tools and shop processes to produce them, affords considerable insight into the influences affecting good machine design. Without introducing any mathematical analysis or investigation, which is beyond the province of this book, much practical consideration as to the restrictions imposed by existing shop methods upon theoretical construction will be suggested, and the student encouraged to use his judgment thereon.

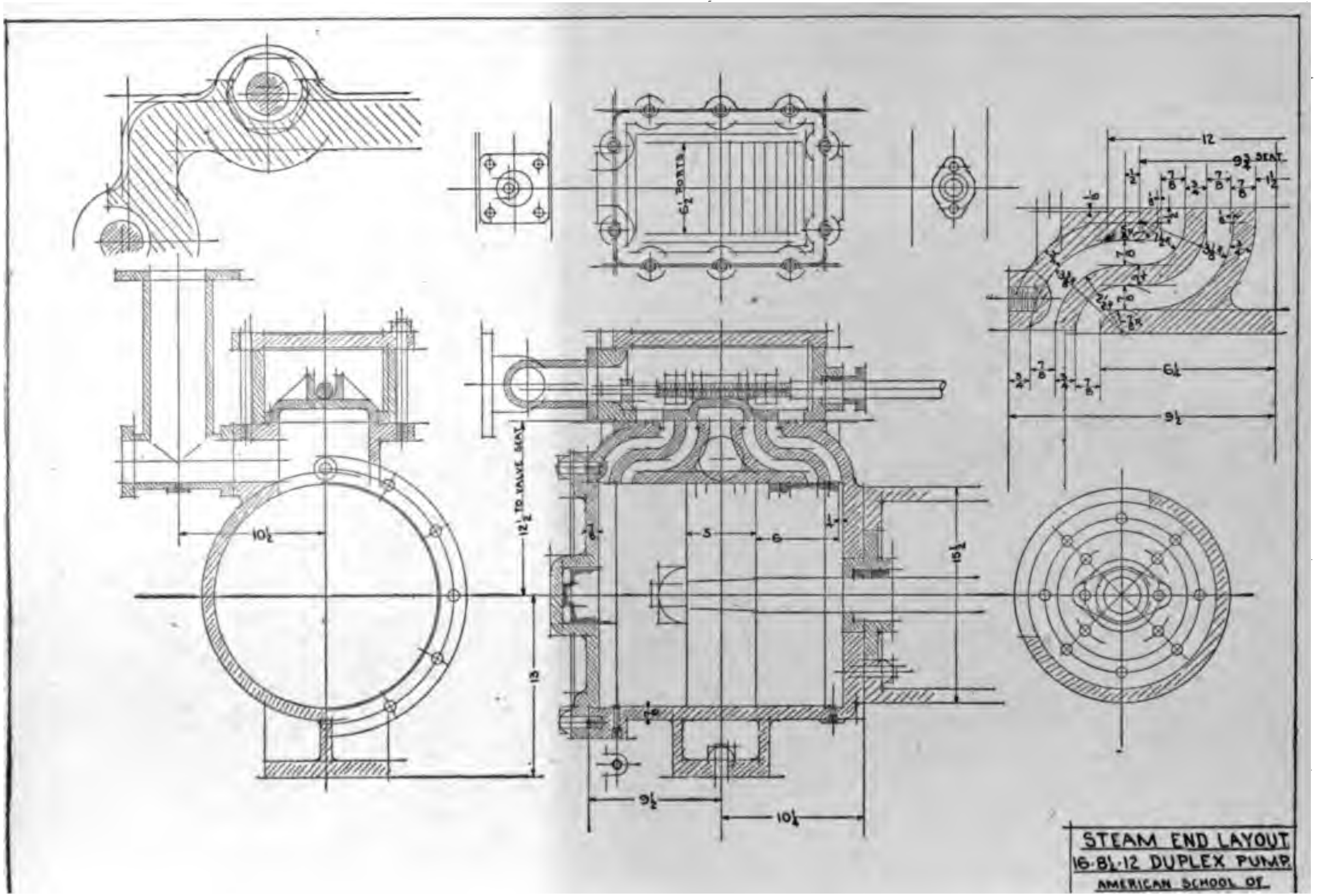
In the preliminary layouts the actual "sketchy" appearance of the pencil drawing will be imitated as far as possible, so that the student himself may imitate and catch the bold dash, yet fine accuracy, of the line-work, which is characteristic of the expert draftsman.

The completeness of a *set* of drawings is as important a lesson as the completeness of each drawing itself. In this is involved the proper arrangement and classification of details, the foundation layout, and the system of order sheets for getting work into and through the shops. This is a feature which very strongly affects some of the finishing touches to a drawing, for it is so easy to omit a "few last things" and turn in an uncompleted sheet. Every draftsman knows how many little things come up toward the close of a job involving complete drawings of a machine, and how strong the tendency is to omit them, and relieve himself of somewhat tedious details. The result is irritation and delay when the drawings get into the shop, and they return to the drawing room to be fixed up at a time probably inconvenient for all parties concerned. A good draftsman will turn in a *complete* set of *complete* drawings. It is highly important that the student grasp this idea, and study his work accordingly.

DUPLEX PUMP PLATES.

The typical set of plates chosen for this book in fulfillment of the above purposes, takes up the study of a simple, duplex steam pump. This particular type of machine represents the simplest and most elementary form of the steam engine in modern use in respect to valve gear and controlling devices. It is not an economical machine, yet its principles lie at the foundation of the economical high-speed engine, the latter being produced through a modification of the uneconomical valve gear such as is found on a pump of the type chosen, rather than through any radical change of construction as to the body of the machine. Hence the study of a steam pump may well precede that of higher forms of the steam engine. It is hoped that the study will so interest the student that he will be led to further investigation and development not only of the steam engine itself, but of that highly important division of modern engineering,—pumping machinery.

Thus we note another point of advantage in the study as out-



STEAM END LAYOUT
16·8½·12 DUPLEX PUMP
AMERICAN SCHOOL OF

lined. The power end of the machine introduces us to the steam engine; the load end is the beginning of the engineering of pumping machinery.

Rating of Pump. A steam pump is rated by the bore of its cylinders and length of stroke, all being given in inches. A "16 × $8\frac{1}{2}$ × 12 pump" means that the steam cylinder is 16 inches in diameter, the water plunger $8\frac{1}{2}$ inches in diameter, and the nominal length of stroke 12 inches. These sizes are always given in the same order, beginning with the diameter of the smallest cylinder (in case there is more than one), then the diameter of water plunger, the common stroke of both being placed last. This expresses to the mechanic the rating of the pump in the clearest style and briefest language.

The pump illustrated here is designed for standard service, operating under a steam pressure not to exceed 100 pounds per square inch, water pressure not to exceed 150 pounds per square inch, and the rated capacity based on an average piston speed of 100 feet per minute being about 550 gallons. This requires that each side of the pump shall handle 275 gallons, and being double acting, shall make 100 reversals or 50 double strokes per minute.

Plate A. Steam End Layout. This plate illustrates, as nearly as reproduction can accomplish, the pencil layout of the steam end. It is the first work of the designing draftsman. The drawing as shown is exactly the type of layout which he would turn over to a detail draftsman, whose duty it would be to work up detail shop drawings therefrom.

The character of this drawing should be carefully studied. Remember that it is a layout, nothing more; also bear in mind that it is an exact, measurable working sketch. Attention is called to the sharpness of the lines, especially to the clean-cut intersections. Note the boldness, dash and businesslike style, the free-hand cross-section lines roughly put in. There is no hesitation or worry as to where the end of a line shall be, or whether it crosses other lines which it theoretically should not. The intersections are allowed to indicate the termination of lines, and the rough section lines pick out the parts and separate them clearly to the eye. There is the spirit in this layout of confident, definite and rapid action, with no thought for absolute finish in line-work, but with every thought for absolute results as to measurable dimensions.

The data for the production of Plate A by the student are rather more complete than he would usually find in practice. Plates E, F and G show many details fully.

The steam cylinder and head, however, as shown in Plate G, are not dimensioned, and the student's problem is to produce this plate complete, with finish marks, dimensions and necessary data for a working drawing. In order to do this it is first necessary to work up Plate A with exactness, in pencil, and see that all parts go together properly. Then the detail of cylinder and head may be made separately by measurement of the layout drawing, and Plate G produced.

For this work the ordinary brown detail paper is very satisfactory. A hard lead pencil is necessary, as hard as 6H, and the point must be kept well sharpened.

There are two general rules of action in producing a drawing which give the answer to the question which oftenest confronts the beginner: "What is to be done first?" or "What is to be done next?" These rules are:

1. Draw everything that is positively known.
2. Work from the inside to the outside.

Every problem has some positive data, assumed or calculated, to start with. The first thing to do in every case is to get this data represented by lines on the paper. An expert designer has been heard to say that until he had spoiled the blankness of his sheet of paper by some lines, he could not design. There is something in this; and almost invariably the first line to draw is a horizontal center line somewhere near the middle of the sheet; draw it! Draw it at once without hesitation, and the layout is begun. We now have something about which to build.

In this case the designer would first calculate the size of the piston rod, and determine the fastening to the piston. He would then draw the rod and build a hub around it. He would next calculate the width or thickness of piston and size of packing rings, and draw the two vertical lines 5 inches apart, to indicate the piston faces. These lines would be limited by the cylinder bore, which he knows to be 16 inches; hence horizontal lines 16 inches apart, parallel to and symmetrical with the center line, are the next to be drawn. Short vertical lines indicate the location of the packing rings. As the nominal travel of the piston is to be 12 inches, the location of the piston and rings can be shown on both sides of the central vertical line at the limits of travel. A clearance must exist between the heads and the piston (in this case $\frac{1}{4}$ inch is allowed), hence the lines of the heads can be drawn, and the general inside outline of the cylinder barrel is complete.

This is all in direct application of the foregoing rules, and is so simple, natural and direct that it hardly requires such explicit statement. We have simply taken such data as we had and put it on paper, placing it where it can be seen from all sides, and where the mind is relieved of the labor of carrying it.

If the student will only appreciate this one rule and draw all he knows about the problem, he is well on his way to its solution. *Draw everything you know, and work for what you don't know,* is what these two rules say, and the first question to arise should be: "Have I drawn everything that is known about the problem?" before he asks himself or any one else: "What shall I do next?"

One other rule might be added to these two: *Keep dimensions in even figures, if possible.* This means that small fractions should be avoided. It is just as easy to bear this point in mind, and save the workman much annoyance and chance of error, as it is to disregard this matter. Even figures constitute one of the trade-marks of an expert draftsman. Of course a few small fractions, and sometimes decimals, will be necessary. Remember, however, that fractions must in every case be according to the common scale; that is, in sixteenths, thirty-seconds, sixty-fourths, etc.; never in thirds, fifths, sevenths, or such as do not occur on the common machinist's scale.

A systematic, definite mode of treatment on these lines must become a habit, so that all problems, however complicated, can be approached with confidence in the same way. It is the drawing of one line which makes clear the drawing of the next and subsequent lines; and the most serious obstacle which the student is likely to set for himself is trying to see the whole problem through from the beginning. Even an expert cannot do this, but allows the layout to develop results as he proceeds.

The details of the piston and rod being given in Plate E, the foregoing work is very easy for the student. The thickness of the barrel and heads being determined ($\frac{7}{8}$ inch in this case), the exterior outline may be partially drawn. The fixed head at the yoke end must be thicker than this, in order to receive the yoke and stuffing-box bolts without breaking through. The recesses or counterbores at either end of the cylinder should be so located that the packing rings run over the edge a little at the end of the stroke, thus preventing the wearing of a shoulder by the piston stopping in the same place every time. The counterbore should be deep enough to allow reboring the cylinder without the counterbore being touched by the tool. In this way the counterbore is retained to center the cylinder at its original location.

The size of steam ports having been calculated, they may be drawn in, the turns being made easy and as direct as possible. The height to valve seat must be kept at the lowest limit consistent with sufficient metal between and outside of the ports. As the detail of the ports might be somewhat troublesome, it is shown in an enlarged sketch for the student's benefit. Chipping or filing strips $\frac{1}{8}$ inch high are left on the port edges, which must be true, in order to finish them up easily.

The three inner ports are for exhaust, the outer ones for admission of steam. This five-ported cylinder is peculiar to the direct acting steam pump, it being a device to effect the cushioning of the piston at the end of the stroke, thus preventing the piston from striking the heads. This is necessary, since no positive limit of motion exists, as is the case in machines with crank and connecting rod.

When the edge of the piston has passed the outer edge of the exhaust port, as shown in Fig. 1, the steam, which has been exhausting through port A, is confined in space B and port C, and, being compressed by the piston, acts like a spring to retard its motion. If the point P is properly determined for a given speed, the piston will always compress the steam just enough to cause it to stop at the end of the nominal stroke; in this case, $\frac{1}{4}$ inch from the head. It is evident, however, that at different speeds the piston will have more or less power to compress the steam, and will not stop at the point desired. This causes the trouble of "short stroke," and consequent inability to make the pump work to its full capacity. Now if we connect ports A and C by a small opening shown dotted at D, and control this opening by a plug valve operated by hand from the outside, we can let a little steam leak by into port A, thus reducing the cushion and allowing full stroke.

In order to avoid complicating the drawing, no cushion valves are shown or required to be put on by the student. They are not customary in small pumps, but might advantageously be put on the present illustration.

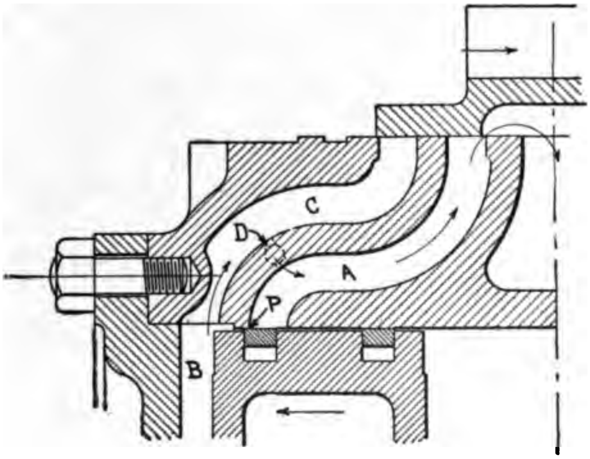


Fig. 1.

The valve seat must be a scraped surface, while the chest face need not be; hence the latter is finished $\frac{1}{8}$ inch lower. This also gives a ledge against which the steam chest fits, thus securing positive location.

The bolting of the heads and the steam chest should allow a width of packing inside of the bolts of $\frac{1}{2}$ to $\frac{5}{8}$ inch, otherwise there is danger of the steam blowing out the packing and causing leakage around the bolts. The bolts do not fill the holes, the latter being drilled large, from $\frac{1}{16}$ to $\frac{1}{8}$ inch. The spacing, if wider than 5 or 6 inches, is likely to permit springing of the flanges between the bolts, and consequent leakage. Bolts less than $\frac{5}{8}$ inch diameter are not desirable, as they can be easily twisted off with an ordinary wrench. In this case the cylinder head takes $\frac{7}{8}$-inch bolts, the yoke, stuffing-box and gland, $\frac{3}{4}$-inch.

The flanges of heads and cylinders are usually from 25 per cent to 50 per cent thicker than the body of the casting.

Drips, $\frac{1}{2}$-inch pipe tap, to be fitted with cocks, are necessary at both ends of the cylinder to readily drain the cylinder of water.

Molding of Steam Cylinder. The design is often influenced by the way in which the piece is to be cast. It often takes but a slight change of design to save many dollars in pattern making and foundry work. Hence the habit should be formed of always judging the design of a piece from the foundry standpoint. In this case it is evident that the ports and cylinder bore must be cored out, and the most obvious position of molding is to lay the cylinder on its side, the parting line of the flask being along a vertical plane running lengthwise through the middle of the cylinder. This permits the chest flanges to draw nicely, likewise the ribs on the foot, and allows the thin curving port cores to stand edgewise in the mold.

Another method of molding would be with the valve seat down. This would involve loose pieces for the chest flanges, and setting of cores for the cylinder foot. It would, however, assure sound metal beyond question at the valve seat. Spongy metal at the important wearing surfaces, the valve seat and cylinder bore, is not permissible in any case, and care in molding, and good design, is necessary for good results.

All corners must be carefully filleted, and chunks of metal must be avoided, especially where several walls or ribs join. The metal must be kept of average uniform thickness, so that the whole casting will cool uniformly.

Machining of Steam Cylinder. The boring may be done on a vertical boring mill, the heavy arm carrying the tool being thrust down unsupported into the cylinder, the latter being rotated by the table to which it is clamped. If the horizontal boring machine be used, the hole through the inside head for the stuffing box must be large enough to permit a stiff boring bar to be passed through. This allows a support at each end of the bar, to take the strain of the cut.

The plane surfaces may be finished on a reciprocating planer

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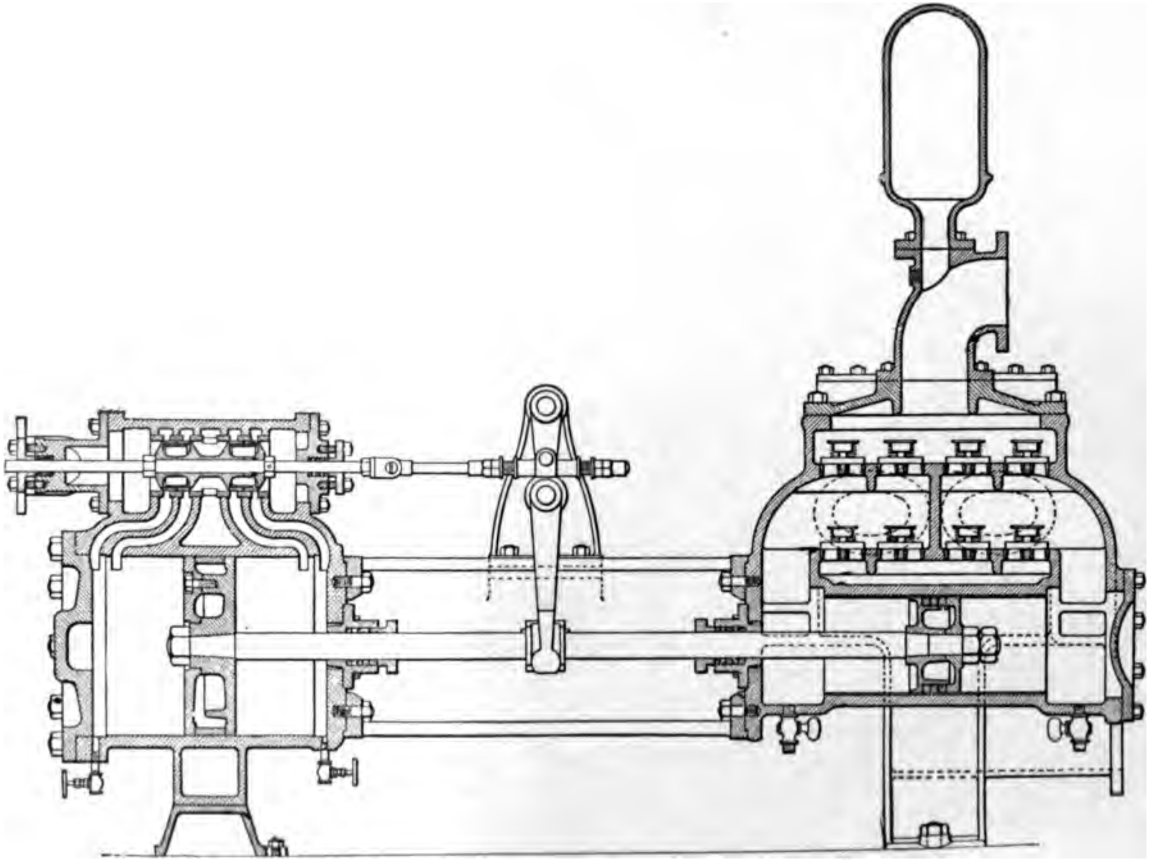


CROSS SECTION OF DOUBLE ACTING STEAM PUMP.

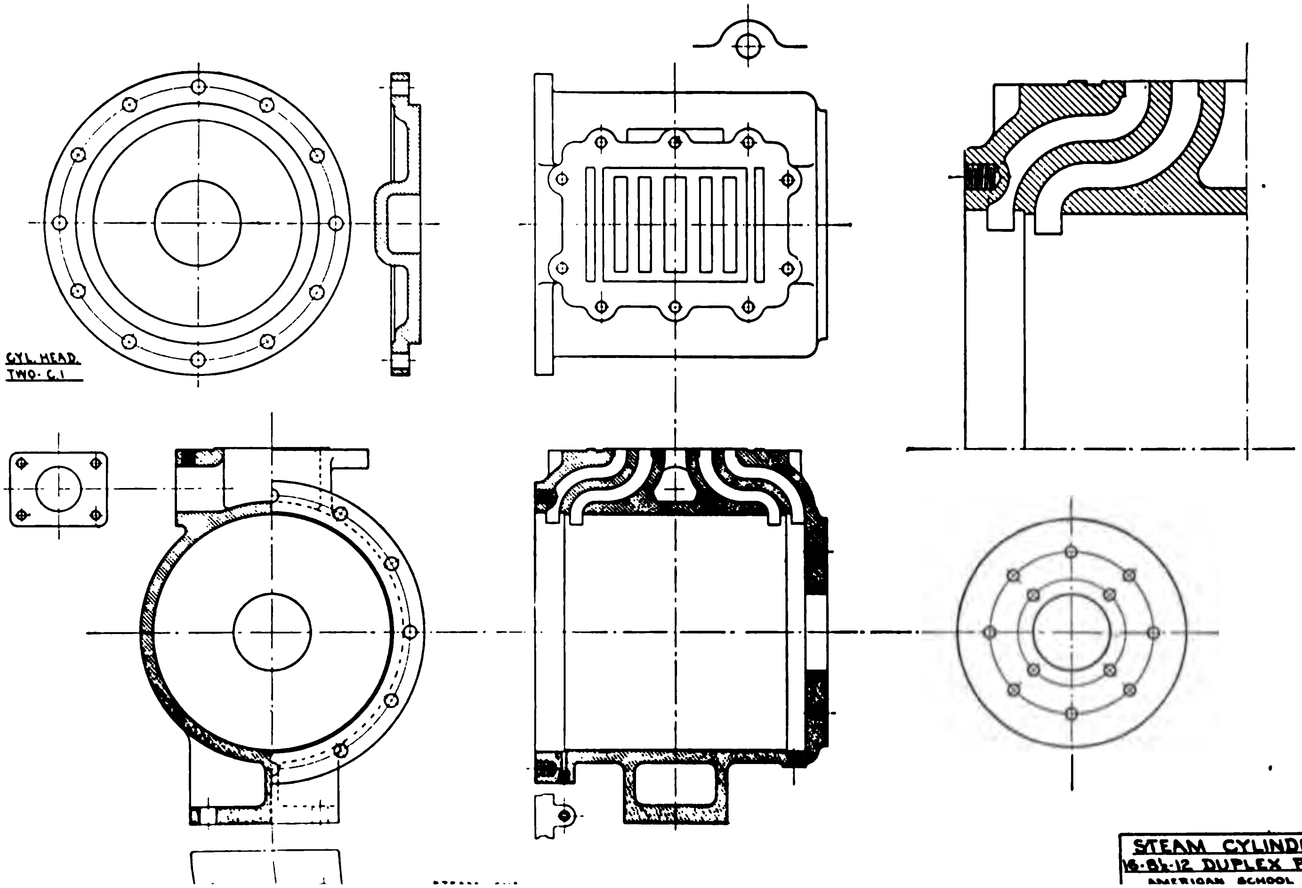
or a rotary planer. In the latter case it is desirable to keep all lugs or projections back from finished surfaces, to permit the large round head which carries the cutters to pass over them without interference.

The drilling of standard machine parts of this character is usually done through jigs, or plates carrying hardened steel bushings laid out to correspond with the holes required, and through which the drill is guided. These plates are located by some fixed line or lug on the casting, and then clamped fast, thus assuring exact duplication and rapid drilling, and avoiding the tedious laying out of the holes. In order to save changing the drill it is desirable, if possible, to maintain the same size of hole on any given surface. Of course it is not always admissible to do this.

Plate G. Steam Cylinder. After the exact and complete development of the steam-end layout, the student should be pretty thoroughly acquainted with the details of the cylinder. All the work thus far has been entirely for *his own* information, to get his ideas in visible shape, so that he himself can have a permanent record of them. This layout, however, is not in suitable form to finish up into a detail drawing. Its sketchy nature and the confusion of parts, especially if attempt were made to add dimensions, would render it somewhat difficult to be read by a workman taking it up as an unfamiliar subject. Hence it is now necessary to separately detail the parts, with the object in view of transferring, in the simplest and most direct manner, specific information to the workman which will enable him to construct the several parts. It is not enough now that the drawing be clear to the man who makes it; it must be clear, *absolutely clear*, to the shop mechanic, who has no means of knowing the designer's plans except through the information which the drawing gives on its face.

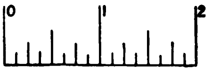
This requires that the draftsman should put himself in the workman's place, and forestall, by the explicit nature of his drawing, all possible questions which may arise in the shop. In this way only can he hope to avoid errors of construction and the continual annoyance of endless explanation of his orders.

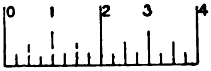
Plate G is to be a finished drawing, and the first thing to do is to lay out the sheet. The standard sheet for details which has

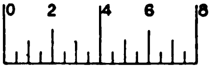


STEAM CYLINDER
16·8½·12 DUPLEX PUMP
AMERICAN SCHOOL OF

been adopted is 18 × 24 inches trimming size, with $\frac{1}{2}$ inch margin all round, so that the working space is 17 × 23 inches. The rectangle for the title is to be laid off $2\frac{1}{2}$ × 4 inches in the lower right-hand corner, and must never be altered, either in size or position. This does not mean that other sizes are wrong, but once a standard system is adopted it must be strictly adhered to, both for artistic and commercial reasons. The scale to which the drawing is to be made is indicated in the title corner on every plate.

The scales permissible for shop drawings in the United States are those readily derived from the common foot rule, such as full size, 6 inches = 1 foot, 3 inches = 1 foot, $1\frac{1}{2}$ inches = 1 foot. These are the most common, most easily read from an ordinary scale, and one of these can usually be adopted. The student should learn to read these from an ordinary scale without being confined to a special graduation. To do this it is not necessary to divide each dimension by 2, 4 and 8 to get half size, quarter size, or eighth size, and then lay down the result. For half size, or 6 inches = 1 foot, $\frac{1}{2}$ inch on an ordinary rule represents 1 inch. Hence, each half inch may be read as 1 inch, and its subdivisions accordingly, thus: 

For 3 inches = 1 foot, or quarter size, $\frac{1}{4}$ inch represents 1 inch, and looks thus: 

For $1\frac{1}{2}$ inches = 1 foot, or eighth size, $\frac{1}{8}$ inch represents 1 foot, and looks thus: 

It is very easy to get accustomed to this, and it saves much time and trouble hunting up a special scale every time.

The other allowable scales, less common, but sometimes necessary on large work, are 1 inch = 1 foot, $\frac{3}{4}$ inch = 1 foot, $\frac{1}{2}$ inch = 1 foot, $\frac{3}{8}$ inch = 1 foot, $\frac{1}{4}$ inch = 1 foot, and $\frac{1}{8}$ inch = 1 foot. To use these scales conveniently, special graduation is desirable.

The general arrangement of the sheet, number of views and approximate space occupied, should be blocked out first. This can easily be done from the original layout. In general, several cross-sections are preferable to a single view, which involves many dotted lines. Dotted lines are very convenient for showing invisible parts of an object, but they are often abused, and the drawing of a complicated piece made indefinite and confused thereby. As already stated, a working shop drawing is solely to convey information to the workman at the least possible cost. A careful consideration of this will settle the question of the number of views necessary, their character, and the amount of dotted line work desirable.

Never let the drawing become the master; always be master of the drawing. Do not draw an extra view if no use can be seen for it. Do not put in dotted lines if the detail is completely shown without them. Full lines, or lines which show visible portions must, of course, be shown completely.

The nature of the pencil work on Plate G should be the same as on the original layout; viz., sharp, definite lines and positive intersections. Above all things learn the habit of accurate workmanship, for it will save many errors and a vast amount of time. The draftsman must check himself at every line he draws. Slight errors in scaling will often throw parts out of proper relation to each other, and interferences, which the drawing does not show, will become apparent only when the parts get into the machinist's hands.

It is dangerous practice to project across from one view to the other. It only takes a slight irregularity or spring in the T-square to vary the location of lines very perceptibly from where they should be, and once out of scale from this reason it is almost impossible to work a view with any certainty. Rather than project across from view to view, the principal lines, at least, should be scaled off on each view, and it will be found that in the end time will be saved and greater accuracy secured.

It is not economical of time to finish one view before beginning another. It is better to take some single detail of the drawing and develop it in all views, in order to study it from all sides. What is completed in one view may be found to be totally wrong when developed from another side, and the time spent on the first view will be wholly wasted. For example, in the present case the steam ports should be drawn in side elevation, end elevation and plan, and when thus completed the mind can leave them and in a similar fashion take up the study of the flanges, then the cylinder foot, and so on. Thus again the draftsman is master of his drawing, for he is continually making it tell him whether he is right or wrong. If, on the contrary, he allows himself to look at but one side at a time, and works from that standpoint alone, it may lead him into many difficulties from which he cannot readily extricate himself.

Do not be afraid to use the eraser. The draftsman who hesitates to draw until he is positive that no change will be necessary, is likely to spend the greater portion of his time in unprofitable dreams, for he is attempting the impossible. A drawing is a means, not an end; and, as has been already pointed out, it greatly assists the draftsman in clearing up many doubtful questions which the imagination alone cannot do.

A bold attack of a problem shows the quickest path to its solution, even if lines must be erased again and again. It is a sign of serious lack of ability to hesitate in the use of pencil and eraser.

Attention is called to the simple, straightforward character of Plate G. Notice the almost entire absence of dotted lines; the enlarged section through the ports, giving ample opportunity for dimensions without confusion; the use of a half end elevation and a half cross-section,—the one to make clear the flange and bolt layout; the other to show the exhaust opening, the small auxiliary views (drawn at convenient points) of the exhaust flange layout, the cylinder foot and the drip boss.

A steam cylinder is a fairly complicated casting; and it would be an easy matter, by the use of elaborate views, the dotting in of parts already completely shown, and careless line work, to rob this drawing almost entirely of its clearness and directness of illustration. *Just what is necessary* (for clearness' sake) *and no more* (for cheapness' sake), is the whole matter in a nutshell, and is what determines its shop and commercial value.

Dimensions and Letters. A good line drawing can be spoiled by poorly arranged dimensions and hasty lettering. The five principal points to be kept in mind to develop excellence in this respect are:

(1) **System.**
(2) **Accuracy.**
(3) **Clearness.**
(4) **Completeness.**
(5) **Character.**

System. The habit of system in placing figures and letters on a drawing is the one element which, to a large extent, controls all the others. If the systematic habit is established early, the other requirements will be fulfilled more easily. A haphazard method will, on the contrary, just as surely prevent the successful cultivation of the ability to figure a drawing. In fact, if the haphazard habit is continued it will itself, by the dissatisfaction which it causes, soon compel the draftsman to change his occupation.

In the first place, whatever part of a machine detail is to be dimensioned, that particular part should receive attention until it has been completely figured. Do not jump from one point to another, putting in a figure here and another there. Stick to one thing until it is done.

For example, take Plate F and the simple detail of the steam pipe. Suppose we start with one of the square flanges. The first question is: "Where is this flange located?" This is answered by the dimensions 5 inches and 21-inch centers, which refer the face of the flange to the center of the pipe and the flanges to each other. The next question is: "What are the three dimensions of the flange,— length, breadth and thickness?" This is readily answered as shown on the drawing. The next question is: "What further description is necessary to completely specify the shape of the flange?" This is answered by the radius of the corners, $\frac{1}{4}$ inch R. Next, "What drilling or special feature exists in the flange?" This is answered by $\frac{1}{16}$-inch drill, $3\frac{1}{2}$-inch centers, and the letter *f* to denote that the face is to be finished.

The round flange of this pipe is approached and figured in the same way, except that the location of the face is preferably referred to the face of the square flange by the figure $8\frac{1}{4}$ inches, instead of to the center of the pipe, because the planer hand will more naturally use this figure.

These flanges are now to be connected by a pipe involving two sizes. The main pipe is 3 inches diameter inside, 4 inches outside, and $\frac{1}{2}$ inch thick, running into the two branches by fillets and radii, as figured. The two branches are really one pipe, $2\frac{1}{2}$ inches inside, $3\frac{1}{2}$ inches outside, $\frac{1}{2}$ inch thick, and sweeping down into the square flanges by 4-inch radius.

This systematic method takes longer to explain than to actually execute, but it is typical of the train of thought which must be followed on all pieces, simple or complicated, in order to properly place dimensions.

In general, it may be stated that all parts of a piece must be referred either to each other, or to some common reference line, or to both. Each part so referred must then be figured as a piece by itself, and then its connections to the principal structure. Thus, figuring a machine detail involves three things:

(1) Relative location of its parts.
(2) Proportions of these parts.
(3) Proportions of connecting members.

As in the original design of a piece so in the figuring of it, the draftsman must as far as possible put himself in the place of the workman, judging the methods and processes of construction and available tools. This will largely influence the arrangement of the dimensions. Of course it implies considerable experience in shop work, which some students do not possess. He can begin none too early, however, to learn to look at his work from the shop standpoint, and surely make it some better on that account.

Pieces must not only be systematically dimensioned, but regularly specified and called for by suitable titles.

A title should specify at least three things:

(1) Name of piece.
(2) Number wanted for one machine.
(3) Material.

To these might be added a fourth; viz., pattern or piece number. The latter is not specified on the drawings under discussion, because systems of pattern and piece numbering are so varied that little would be gained by developing one for this special study.

These titles should always be put on in the same way, as the workmen become used to a certain system and are likely to misunderstand directions if a regular plan is not followed. A good way to arrange titles is suggested on the plates, although there are others which might be used.

Bolts are usually specified by diameter and length under the head, the length of thread being to some standard system in use by the shop, unless otherwise called for. Bolts are specified on the sheet containing the piece into which they are tapped. In the case of through bolts, tapped into neither piece, they are preferably called for in connection with the principal member.

Accuracy. Of course the dimensions on a drawing must be accurate. It is, however, a very easy matter to make errors. To insure accuracy a figure must *never* be put down carelessly, and a constant watch must be kept that scaled figures add up to over-all dimensions. It will not do to rely on scaling alone, as a very slight variation from exact scale may throw two dimensions out with each other. In spite of all the care that can be exercised errors will creep in, and a final thorough checking must be given a drawing before it is pronounced complete. A good rule to follow in checking up is to "assume everything wrong until it is proved to be right."

Clearness. As in the line drawing itself, there must be absolute clearness of instruction by the dimensions. Any doubt as to what a figure is, or what it means, rules out that figure as part of the drawing. If a piece is made wrong because doubt of this character is transmitted to the workman, the draftsman is always held responsible for the error.

Figures should, in all cases, be placed where they can be most clearly read. They should be bunched on a single view as far as possible, but not when greater clearness demands that another view be used. It hinders the reading of a drawing materially if the eye is forced to jump over large spaces of the sheet from view to view, to catch the several dimensions of a small detail. Usually it is easy to so group figures as to avoid this.

It is a good plan to keep dimensions off the body of the drawing, when it can be done so conveniently. It is not worth while, however, to go out of one's way to do this, as figures in the open spaces of a detail do not at all destroy its clearness.

Extended notes on a drawing to make it clear should not be required, but they should be used without hesitation if any doubt exists. An explicit note of instruction is the final resource for clearness when the art of drawing fails of its purpose, as it sometimes does.

Completeness. A detail is completely dimensioned when it shows *all* the figures necessary for the workman. Anything short of this is incompleteness. As modern shops hold the draftsman solely responsible for the design, the mechanic is not allowed to modify it by filling in any omitted dimensions. The only way to be sure that all the dimensions are on is to systematically go all round a piece inside and out, according to the method suggested under the paragraph on "System."

It is a good plan to always bear in mind that not only the machinist is to use the drawing, but also the pattern maker. For the benefit of the latter, special attention is desirable in figuring the cores. This saves him some addition and subtraction. In general, it has been found that less chance of error exists if mathematical work is not required of the shopman, all necessary data being furnished on the face of the drawing.

Character. By character in figures and letters is meant uniform style, height and slope, and a certain boldness peculiar to the work of the expert draftsman. The last is difficult for the novice to acquire. The student should not be discouraged because his efforts do not look like impressions from printers' type. Artistic excellence is the result of long experience, but is based on character. If the student can once get character into his work, the artistic feature will, with careful and constant practice, gradually develop. It is safe to say that there is no one element of a drawing which more positively stamps it as the work of an amateur than the character of the lettering, and every attention should be paid to getting out of the apprenticeship stage in this respect. Freehand lettering only is permitted in the drawings illustrated herewith. Ruled letters are seldom found on any working drawings, as the element of time involved is so great that few shops are willing to pay for it.

Uniform style requires that if capitals only are used in titles, they only must be used in notes and elsewhere on the drawing. If lower-case letters are used, they must be used in every part of the drawing. One style should not be mixed with another. The height of the letters should be limited by two horizontal lines, and though practice may render the upper line unnecessary, it takes but an instant to draw it, and uniform height is then assured. A good height for titles of details such as are illustrated is $\frac{5}{32}$ inch. The height once chosen should be adhered to throughout the whole set. A medium, not a hard, grade of pencil (3H) will give the hand greater freedom. A great temptation exists to omit titles from the pencil drawing, simply inking them on the tracing. This is false economy of time, for in the end it will be found that enough time will be saved by the certainty with which the tracing can be made to more than pay for the labor on the pencil drawing. Again, it permits the tracing, in regular shop practice, to be made by cheaper labor than that which produced the pencil drawing.

Uniform slope is most easily acquired by the use of guide lines put in at frequent intervals. A small wooden triangle can be made, giving the required angle. The angle of the letters shown on the plates is 9 degrees, or about 1 inch slope in 6 inches. The question as to whether letters should incline backwards, forwards, or stand vertical, does not enter this discussion. Character is not affected by the slope. The student may choose whatever comes most natural to him, but having chosen, the character of his work will be spoiled if he varies it. The most difficult of the three is the vertical style; hence most draftsmen incline their letters. The backward slope is used on the plates of this shop drawing paper, thus giving the student opportunity to compare with plates in the earlier books, and follow his preference.

The effect of change of style, height and slope is shown in Figs. 2, 3 and 4, respectively. Attention is called to Fig. 5, which is a sample title, in which these points are corrected.

Principal Titles. The principal title of a drawing should contain at least seven items:

(1) Name of principal details shown.
(2) Name of machine.
(3) Firm name and location.
(4) Scale of drawing.
(5) Date of completion.
(6) Draftsman's signature.
(7) Filing number.

To these are often added others, but for purposes of filing and reference the above at least *must* be put on. The filing number may or may not be put in the title frame, but it is really a part of it. It is often put in the margin below the title.

An arrangement of title should be established and then followed exactly, without variation either as to location on sheet or detail make-up. Abbreviated words are always permissible in titles, provided the meaning is clear. Special care must be taken in punctuation, however, as a title, whether abbreviated or not, has an unfinished appearance if the periods, commas and other necessary punctuation marks are not included.

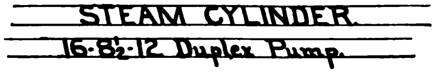


Fig. 2.

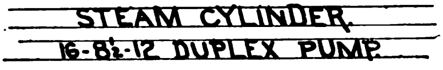


Fig. 3.

The sample title illustrated in Fig. 5 indicates the arrangement chosen for the drawings of Part IV. Note that it is necessary in this special case to add an extra subject to the seven given above; viz., the residence of the student draftsman.

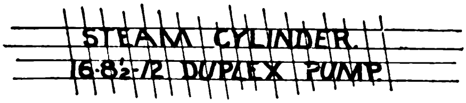


Fig. 4.

This style of title must be put with care on every drawing, even on the rough pencil layouts. In the latter case it may of course be left in pencil, as the rough layouts are not to be inked.

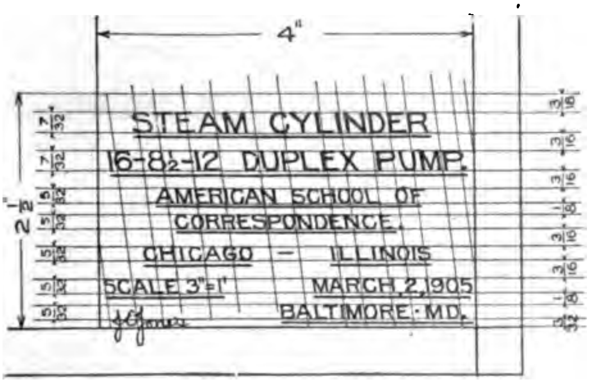


Fig. 5.

Inking and Tracing. Both bond paper and tracing cloth are used in business practice for finished drawings. It is desirable to keep a stock of both in any drawing office, so that either may be used as occasion requires. Bond paper stretched on the board gives a beautiful surface to take the ink, and very handsome and effective detail or assembled drawings can thus be produced.

Changes are not quite as readily made on bond paper as on tracing cloth, and it takes a little longer to make the blue print. In other ways the bond paper is not quite as flexible to use as the tracing cloth. However, one must be guided entirely by shop conditions to settle the question of preference. As the tracing cloth is generally used, and suits the purpose of the student better, it will be required in this work.

The inking should be done on the *rough* side of the cloth. One reason for choosing this side is that as the cloth tends to curl under toward the glazed side, the drawing as it lies right side up will tend to straighten itself. This seems to be a small point, but it is a very important advantage for filing and for the convenience of those who are to handle the drawings. Also the rough side takes colors and inks better than the glazed side. To trace on the glazed side is not wrong, for it is often done, but it possesses no advantages of its own, and has the disadvantage mentioned above.

Chalk dust scattered over the surface of the cloth after it is tacked down will remove the slightly greasy coating which prevents the ink from flowing well from the pen. This is always necessary if the glazed side be used, and usually for the rough side. The chalk must be carefully removed from the cloth before inking.

The first step in inking is to draw the center lines. Remember that *accurate intersections* are of the utmost importance. No circle is complete without two intersecting lines, preferably at 90 degrees, to determine its center, and these lines should be inked before the circle. When this is done a definite point exists for the needle point of the compasses. If the circle is drawn first the needle point may not be placed accurately at the center on the pencil drawing beneath, and the location be thrown out.

Likewise the principal center lines of pieces, the lines around which the pencil drawing was built up should be at once put in.

The main body of the drawing, the full lines, should be taken next. In general, circles and arcs should be inked first, but there are cases where it is easier to run the arcs into the straight lines than to match the straight lines to the arcs. They are exceptions. however, and can be judged only as the case arises.

Straight lines, horizontal and vertical, should be inked with the T-square and triangle *in position.* It is a common practice to dispense with the use of the T-square entirely in inking in, using the triangle to match the lines to the arcs already drawn. A necessity for this implies very poor work on the arcs, for with any reasonable care true horizontal and vertical lines will match the arcs all right. With regard to time required, the accuracy with which the T-square may be brought up to a line, or the triangle set on the T-square, more than makes up for the time gained in even an approximate setting of the triangle without a guide. It is just as easy to cultivate the habit of holding the T-square and triangle with the left hand and the pen with the right, and draw an exact line, as to lapse into the other method, which is not workmanlike.

The lines of the body of the drawing depend for their width upon the size of the detail. For a large piece they may be $\frac{1}{32}$ inch wide, and the shade lines $\frac{3}{64}$ inch. For a small detail such widths would be too great. Remember that *contrast* is the principal aim, and to produce it is the only reason why we use different kinds of lines on a drawing. Hence the greatest care must be exercised to prevent body lines from becoming confused with center or dimension lines, and *vice versa.* Also thick lines are desirable for the production of a bold blue-print.

Shade lines are shown on Plates I, K and N only. They are put on according to principles already explained. They certainly improve the drawing from an artistic standpoint, and the student should know how to put them on when desired. Whether or not it is desirable to adopt them on all working drawings is not the purpose of this book to decide, or even discuss. Almost always drawings can be made perfectly clear without them, and are so made and satisfactorily used in probably the majority of shops. Some shops are willing to pay for the extra time necessary to put on shade lines; this, however, is purely their own investment.

Cross-section lines are usually drawn at an angle of 45 degrees with the horizontal, and on sections which are adjacent to each other the slope should be in different directions. If three or more sections come together the width between section lines can be so changed as to indicate clearly the different parts. An example of this is shown in Fig. 6.

The spacing of section lines must not be too fine, rarely closer than $\frac{1}{16}$ inch, more often from $\frac{3}{32}$ to $\frac{1}{8}$ inch, else the labor involved is too great and uniformity practically impossible. It is a waste of time to rule in section lines on the pencil drawing; they may be sketched in freehand, as shown on the original layout of the steam cylinder. Even spacing concerns the tracing alone, and the student should train his eye to regularity as he traces The thickness of section lines may be intermediate between that of center lines and body lines of the drawing.

Inking Dimensions and Letters. Extension lines may be dotted, as explained in Part III, or they may be fine, full lines, the latter method being illustrated in the series of pump plates in this paper. Dimension lines are also often made fine, full lines. If these lines are made full they should be made as fine as it is possible to draw them and still have them firm, clear lines. The same width should be used as for center lines.

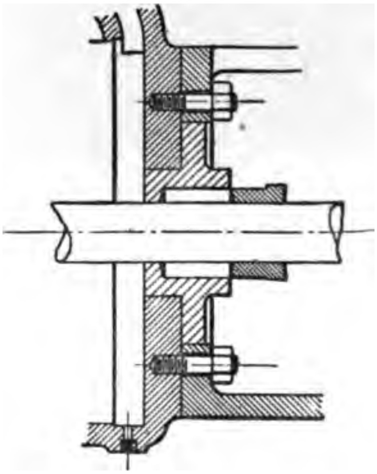


Fig. 6.

Character in inked figures and letters is more difficult to attain than in pencil work. In the first place a pen suitable to the style of drawing is necessary. A civil engineer's fine mapping pen, which gives character to his drawing, is not desirable in producing the bold character of a machine drawing. For the latter choose a rather stiff, blunt pen which is not "scratchy, but runs smoothly, making a line of uniform width. A pen with a round, or ball-shaped nib, recently put on the market, answers the purpose well for ordinary details. A bold, free stroke should be made with the idea of producing a smooth, even line, finished at the first trial. The hesitating uncertainty of the beginner's hand produces a "shaky" letter, and going over a letter or figure twice or more to smooth it up usually makes it worse.

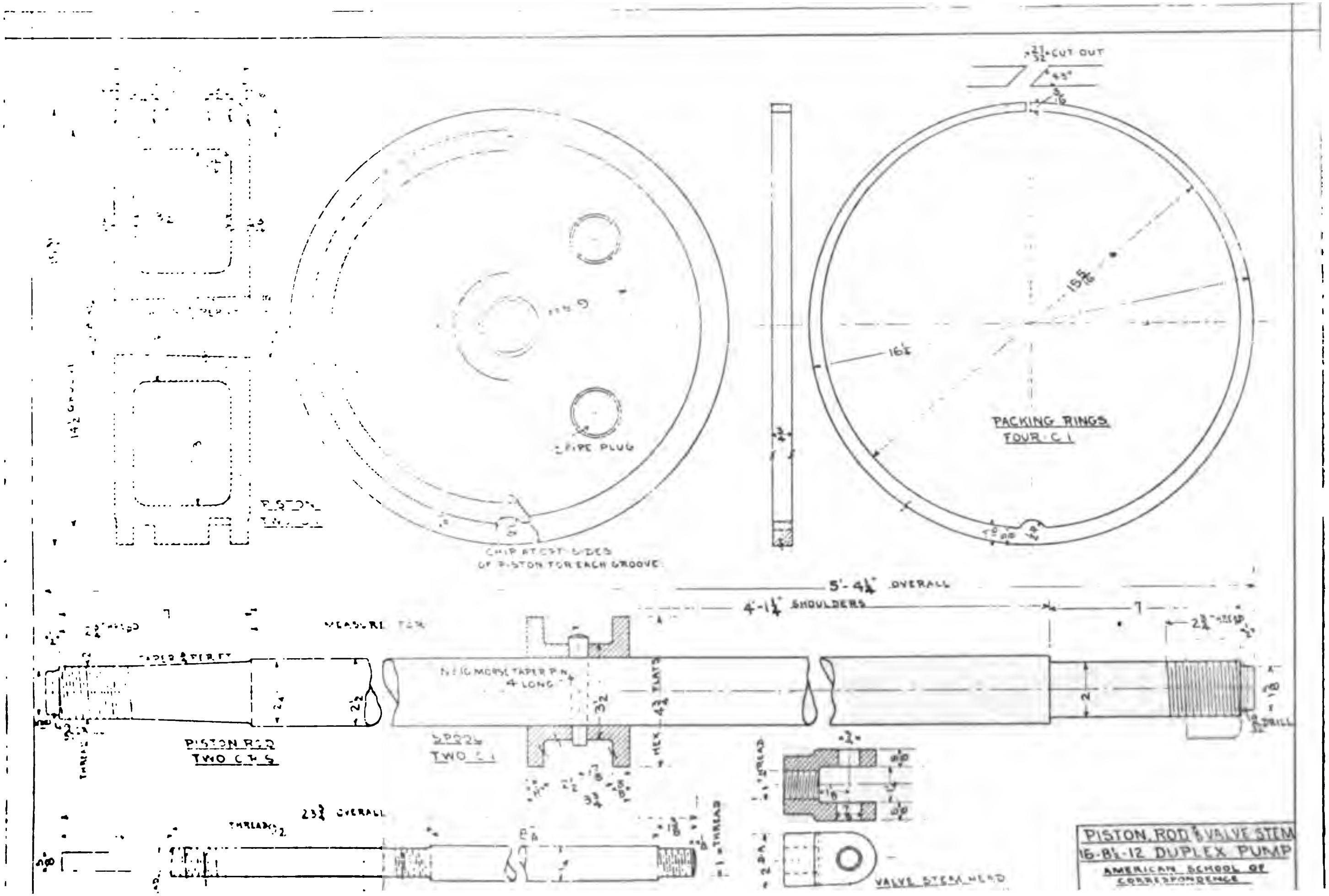
Figures and letters which are broad in proportion to height are easier to make, and have more character. It should never for a moment be forgotten that uniform *height* and *slope* carefully followed will develop character and quickly lead to artistic excellence.

Foot and inch marks are often put after figures according to the common usage. In cases where feet and inches are expressed, thus: 3′ — 6″, or 4′ — 0″, they are, of course, absolutely necessary, and the dash between the figures must be very positively indicated. In cases of inch dimensions alone the marks may be put on if desired, but where there can be no doubt that inches, and not feet, are meant, the inch marks are not necessary. This practice is followed on the plates of this paper.

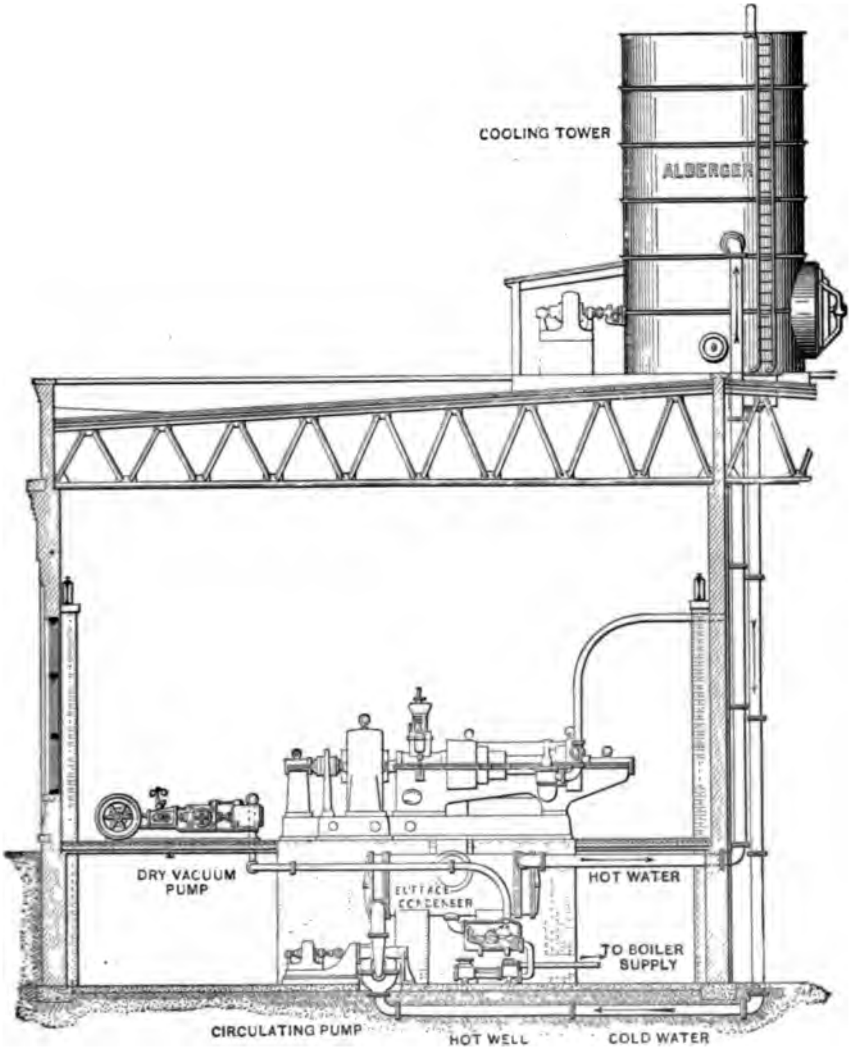
Abbreviations. A list of the most common abbreviations in use on working drawings follows. This list has been adopted for the plates in Part IV:

F. A. O.	finished all over.
f.	finished surface.
R.	radius.
D.	diameter.
R. H.	right hand.
L. H.	left hand.
P. R.	piston rod.
P. TAP.	pipe tap.
CTRS.	centers.
C. I.	cast iron.
S. C.	steel casting.
Bz.	bronze.
C. R. S.	cold rolled steel.
T. S.	tool steel.
O. H. S.	open hearth steel.
W. I.	wrought iron.

Plate E. Piston Rod and Valve Stem. The piston is of the one-piece box type, with sprung-in rings. The width is reduced to $4\frac{7}{8}$ inches at the outside, so that if the piston strikes the cylinder heads it will not tend to spring and break off the narrow ridge of metal outside of the packing ring. The piston rod is fastened to the piston on a taper drawn in by a nut, and the



PISTON ROD & VALVE STEM
16-8½-12 DUPLEX PUMP
AMERICAN SCHOOL OF CORRESPONDENCE



COOLING TOWER AND SURFACE CONDENSER AS APPLIED TO STEAM TURBINE.
Alberger Condenser Company.

THE NEW YORK
PUBLIC LIBRARY

ASTOR, LENOX AND
TILDEN FOUNDATION

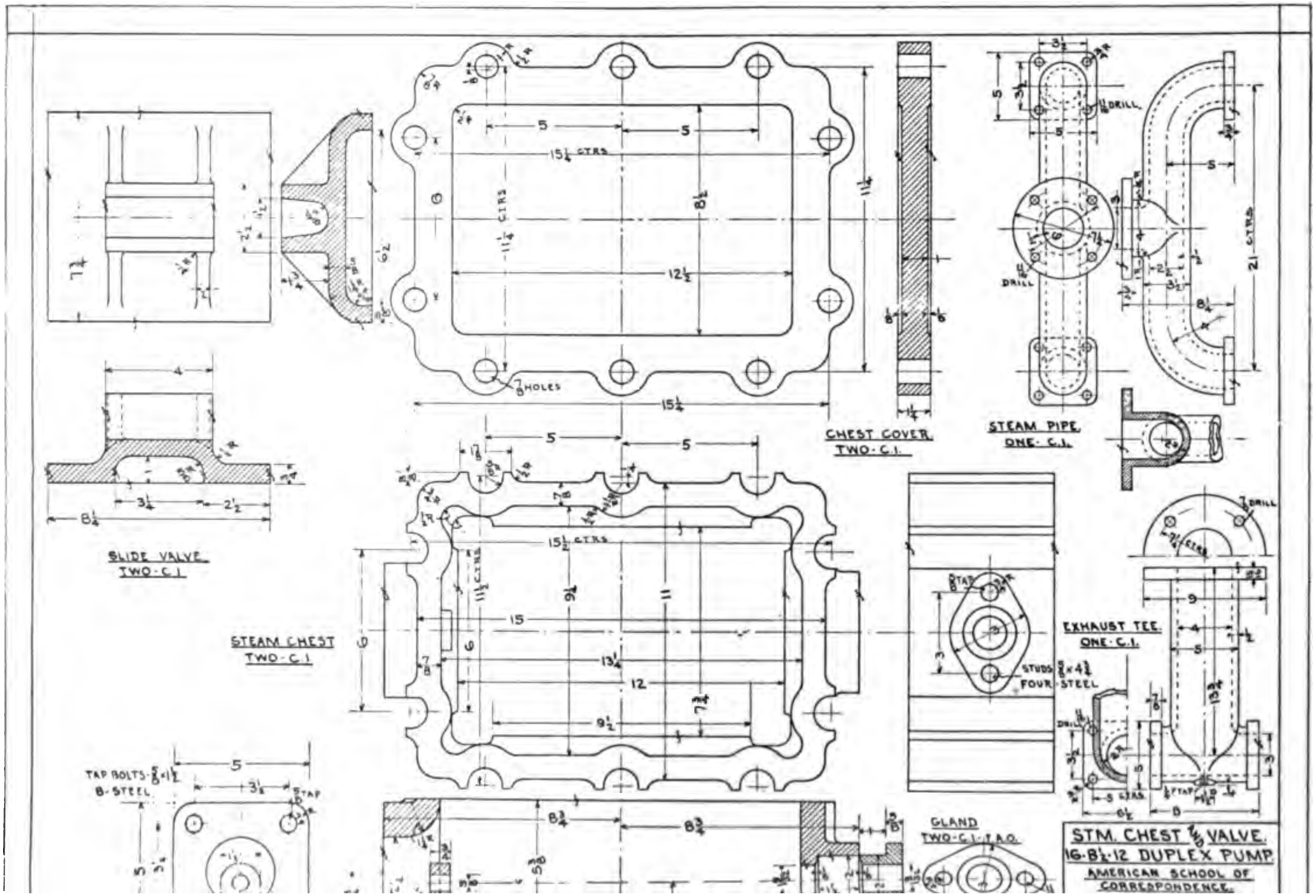
nut is checked by a ¼-inch split pin. The packing rings are prevented from slipping round the piston by lugs fitting loosely in chipped recesses in the groove. These being at opposite sides for each groove, the leakage of steam through the split in the ring is minimized, for it must pass half way round the piston before it can pass through the split in the other ring. This is a simple, but fairly effective, device.

The packing rings are usually cast in the form of a cylinder of some length, turned to a diameter a little larger than the cylinder bore, cut off to the required width, and sufficient space cut out to permit being sprung in to the size of cylinder bore.

The location of the spool on the piston rod is not positively known, as the setting of the valve bracket may be slightly different from what the drawing calls for. Hence, instead of a dimension, the words "measure for" are put on, to indicate that the spool be located during the erection of the pump. The hexagonal flanges of the spool are convenient to hold the rod from turning while screwing on the piston and plunger nuts.

Molding and Machining. There are no special features connected with the molding and machining of parts on Plate E. The holes in the piston side walls are necessary to give supports for the core, the piston being cast on its side. These holes, after the core is cleaned out through them, are plugged as indicated.

Plate F. Steam Chest and Valve. The steam chest in this instance is located on the cylinder by fitting down over the ledge made by the valve seat. The side flanges also serve the purpose of guiding the valve. It will be noticed that the steam chest cover is 15¼ inches × 11¼ inches, while the steam chest is 15 inches × 11 inches. This allows a ledge of ⅛ inch, all around which the cover overhangs the walls of the chest. The steam cylinder flange in order to correspond must likewise be 15¼ inches × 11¼ inches. The reason this is done is because of the difficulty of making good matched joints between the cylinder flange, chest and cover. The practice of thus leaving a little ledge all round is by no means universal, and often the irregularity in the joints is smoothed off by chipping. This is the case with the other flanges on this pump. The steam chest, however, was thought less likely to match properly, and the slight overhang gives the finished appearance of a sort of beaded edge.


STM. CHEST AND VALVE.
16-8½-12 DUPLEX PUMP.
AMERICAN SCHOOL OF CORRESPONDENCE.

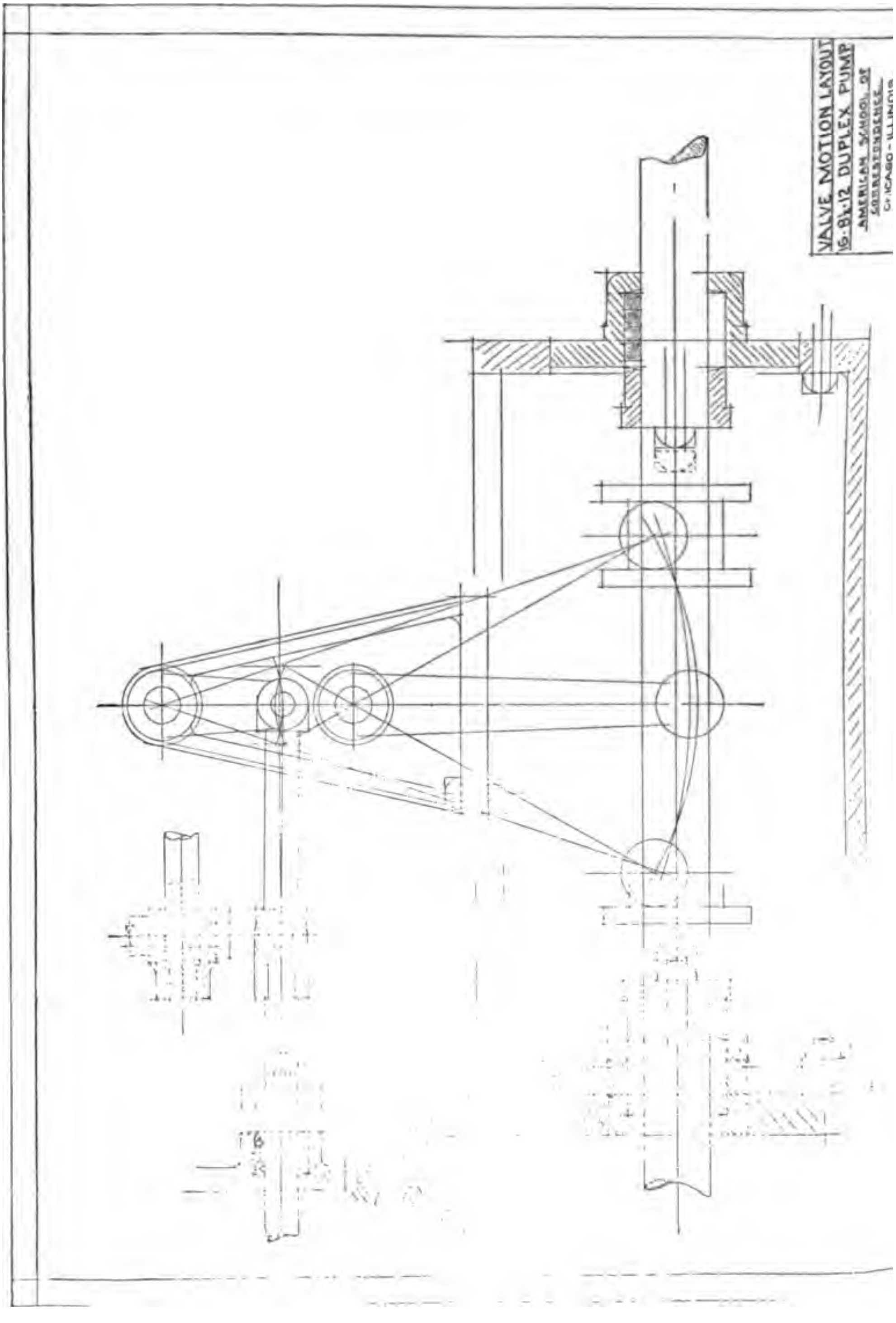
The valve is what is known as a "square" slide valve. This means that when the valve is placed central on the ports its working edges are "square" with the ports; that is, in exact line with them. If the valve be moved either way from this position, the slightest travel will admit steam to one end of the cylinder and exhaust it from the other. (See Plate A.) Another way of stating this is to say that a "square" slide valve is a slide valve without "lap."

The valve is driven from the valve stem by the striking of the nuts against the lug on its top. Since the valve is already guided on its edges by the steam-chest flange, the valve stem, to avoid springing, must be perfectly free in the slot cast for it, as is shown by the $\frac{5}{8}$-inch radius of the bottom, the stem being 1 inch in diameter.

The steam-pipe flange is made square to keep the height of the chest as low as possible. The radius of the bend should be ample; in this case 4 inches is considered sufficient.

The exhaust tee must have its upper flange high enough so that the chest cover can be lifted and slipped off the studs without interfering with it. The lower flanges should be made wide enough to permit the tap bolts to be put in without striking the 4-inch vertical pipe, 5-inch centers being necessary. The $\frac{1}{4}$-inch drip-cock, as located, readily drains the steam chest and exhaust passage of both cylinders, as well as the exhaust tee.

Molding. It is evident that the steam chest will be molded in the position shown on the drawing. The parting line of the mold will be through the centers of the steam-pipe opening and the stuffing-box. These holes must be cored out. The main body of the chest could be made to leave its own core, but it may not be made in this way. It may be cheaper to fashion the pattern solid, and make one large core-box for the inside. In this way the pattern will probably hold its shape better and require less repairs, than if it were made in green sand. The core-box will be an extra piece to make, but it probably will cost no more than to carve out the inside of the pattern, and is a rather more substantial job when done. The molding can be satisfactorily done by either method, shop conditions being the controlling element. As far as the labor of molding alone is concerned, the first method is probably easier, as it saves handling large cores.



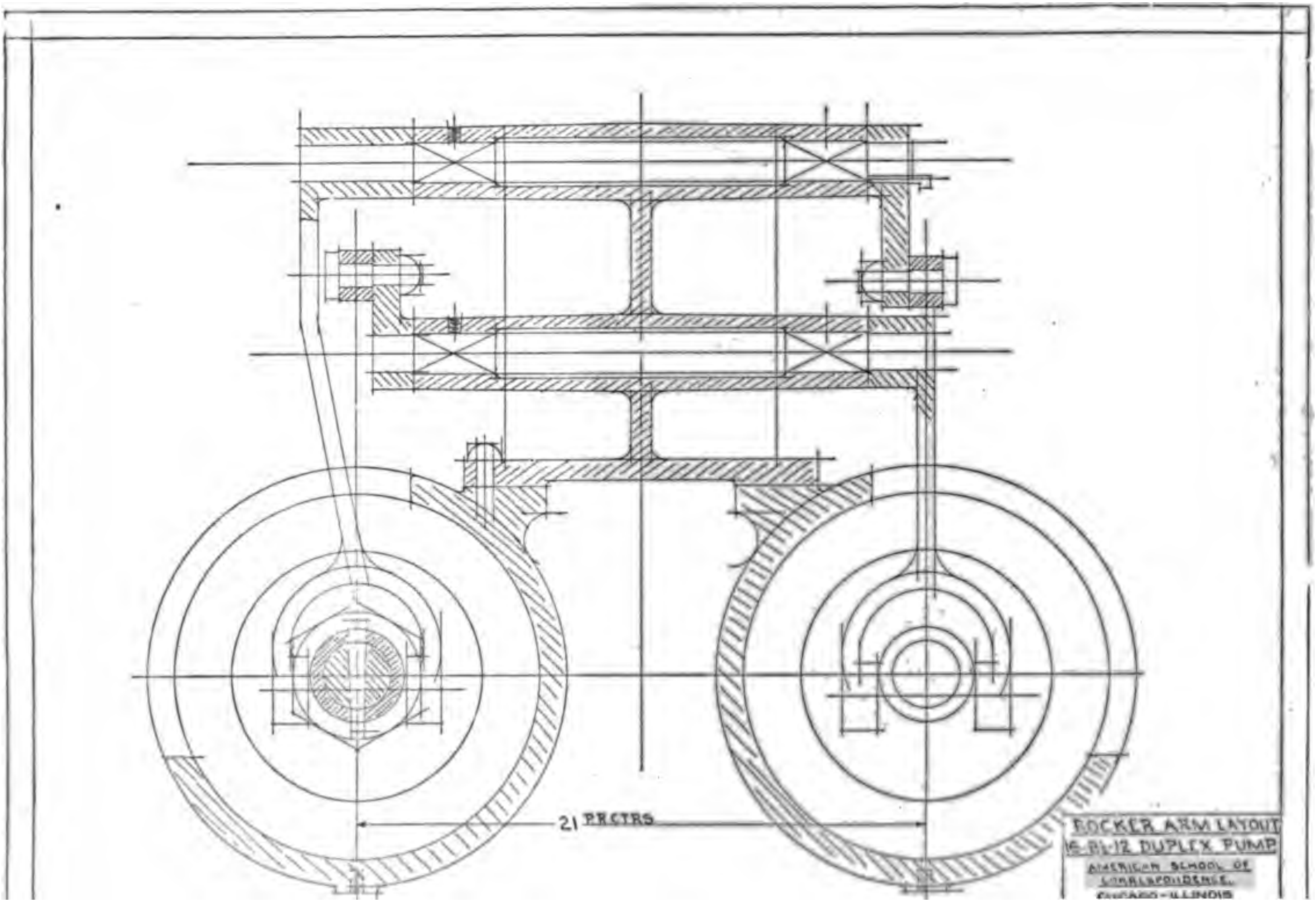
VALVE MOTION LAYOUT
16-8½-12 DUPLEX PUMP
AMERICAN SCHOOL OF CORRESPONDENCE
CHICAGO - ILLINOIS

The other parts in Plate F are very simple in their molding, and require no special attention.

Machining. Most of the surface work on this plate is adapted to the planer. The slide valve may, perhaps, if finished in lots of considerable number, be more satisfactorily handled on the milling machine. The final finish of the face of the valve must be a scraped fit to its seat.

The drilling of the cover and pipe flanges is to actual layout on the casting, or preferably, through jig plates. A templet for laying out is at least desirable, even though the expense of a jig plate be not deemed necessary.

Plates C and D. Valve Motion Layout. These plates represent the layout of the valve motion, and are necessary in order to find the length of the levers and rocker arms. It will be noticed in Plate D that the valve stem of one side of the pump is controlled by the movement of the piston-rod of the other side, the proper direction of motion being given to the valve by placing the rocker shaft above or below the valve stem as required. By reference to Plate A it will be further noticed that the nuts on the valve stem inside the chest, which abut against the faces of the lug on the valve, do not rest against the faces of the lug in the position shown, but have considerable lost motion. This lost motion is one of the essential features of the valve motion of a duplex pump, and permits the valve to remain at rest for a short period at the end of the stroke, though the valve stem may have reversed its motion and begun its return stroke. When this lost motion is taken up by the movement of the stem and the nuts abut against the lug on the valve, the valve will move, and from this point to the end of the stroke be positively controlled by the motion of the stem. At the end of the stroke the stem will reverse, when the lost motion will again permit the valve to rest for the same period as at the other end, and then move on as before. The time of rest of the valve, and consequently the pistons and plungers, is approximately one-third the period of the stroke. This means that the piston on one side travels one-third of its stroke before it picks up, through the valve levers, the valve on the other side. During the second third of its travel it is bringing the

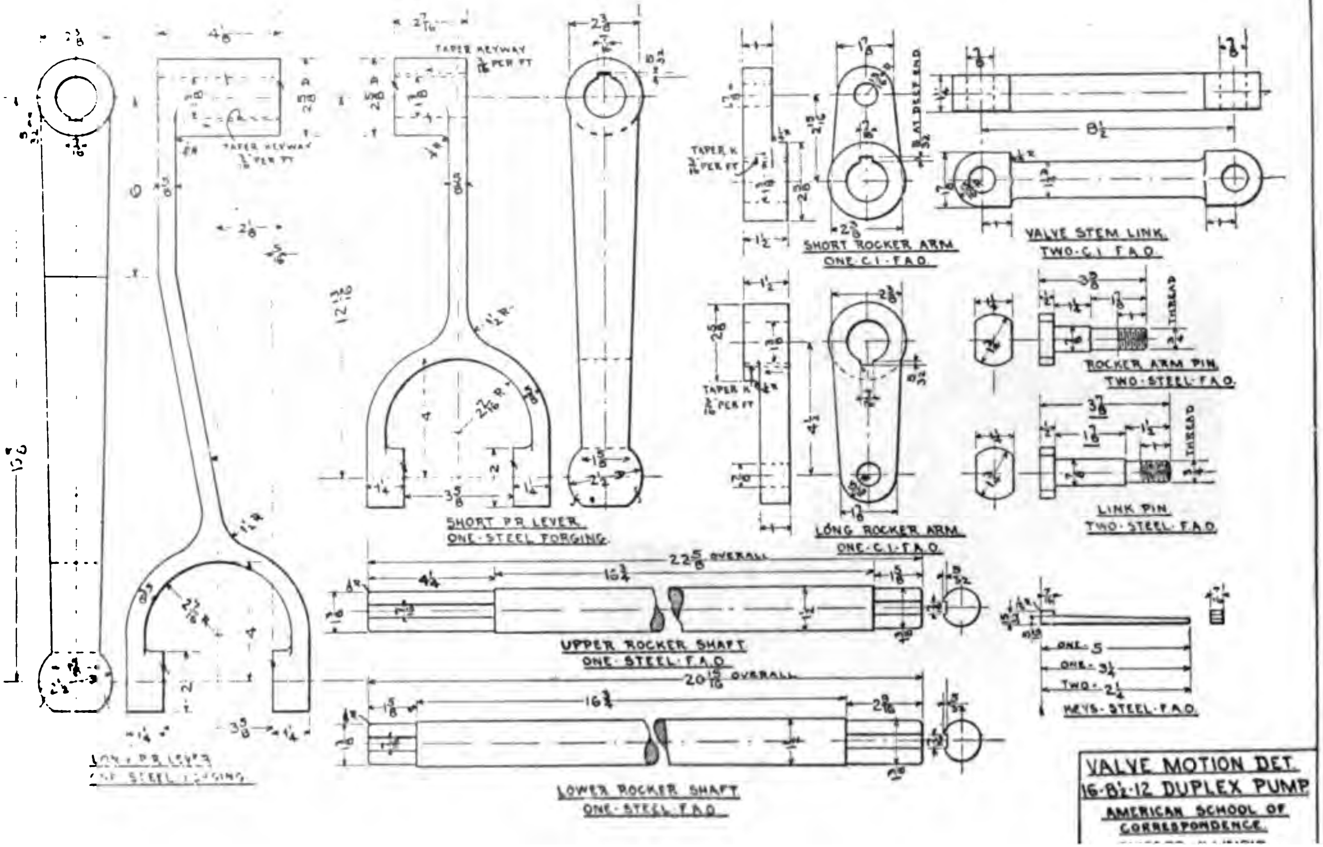

21 PR CTRS
ROCKER ARM LAYOUT
16-8½-12 DUPLEX PUMP
AMERICAN SCHOOL OF
CORRESPONDENCE,
CHICAGO - ILLINOIS

valve to the point of opening. During the last third of its travel it is opening the port, wider and wider, to steam. Thus the opposite piston will start when the first piston has covered two-thirds of its stroke, and there will be only one-third of the stroke when both pistons are moving at the same time.

This relative period of rest to motion is not always made in this exact ratio, but is at least approximate to it. The period of rest at the end of the stroke is to allow the water end to adjust itself quietly to the reversal of motion about to take place at the end of the stroke. When the plunger stops, the water valves must be given time to seat themselves, and the flow of water through the passages checked. It is much easier to start the flow in the opposite direction if the reversal of plunger motion is not instantaneous. Hence for handling long columns of water, which, once in motion, tend by considerable energy to remain in motion, the duplex pump by this peculiar delayed action has been found to be well suited.

It will be found that for complete uncovering of port, and motion divisible into thirds as described, the travel of the valve stem should be three times the width of port, or $3 \times \frac{7}{8}$ inch $= 2\frac{5}{8}$ inches. A little more than this is allowed, and the travel made $2\frac{7}{8}$ inches in this case. Referring to Plate C, this distance is laid off as shown by the two limiting vertical lines across the line of the valve stem, the central vertical line of mid-position being drawn. The problem then is to find such centers for the rocker arms that the travel of the piston-rod spool will, through proper leverage, produce travel of the valve stem between these two vertical lines. This can readily be done by a few trials, the only requirement for this case being that the extremes of the arc of swing of both piston-rod lever and rocker arm shall be equally above and below the center of piston rod and valve stem respectively. The greatest possible travel of the piston-rod spool, $12\frac{1}{2}$ inches, is usually laid out in this case, not the nominal 12 inches.

From this layout the lengths of the levers and arms may be scaled off for the detail drawing, also the location of the rocker-arm centers. The student has the former given him on Plate K, but the latter, which is necessary for the development of Plate L, must be determined by his own layout. Plate D must also be



VALVE MOTION DET.
16-8½-12 DUPLEX PUMP
AMERICAN SCHOOL OF CORRESPONDENCE

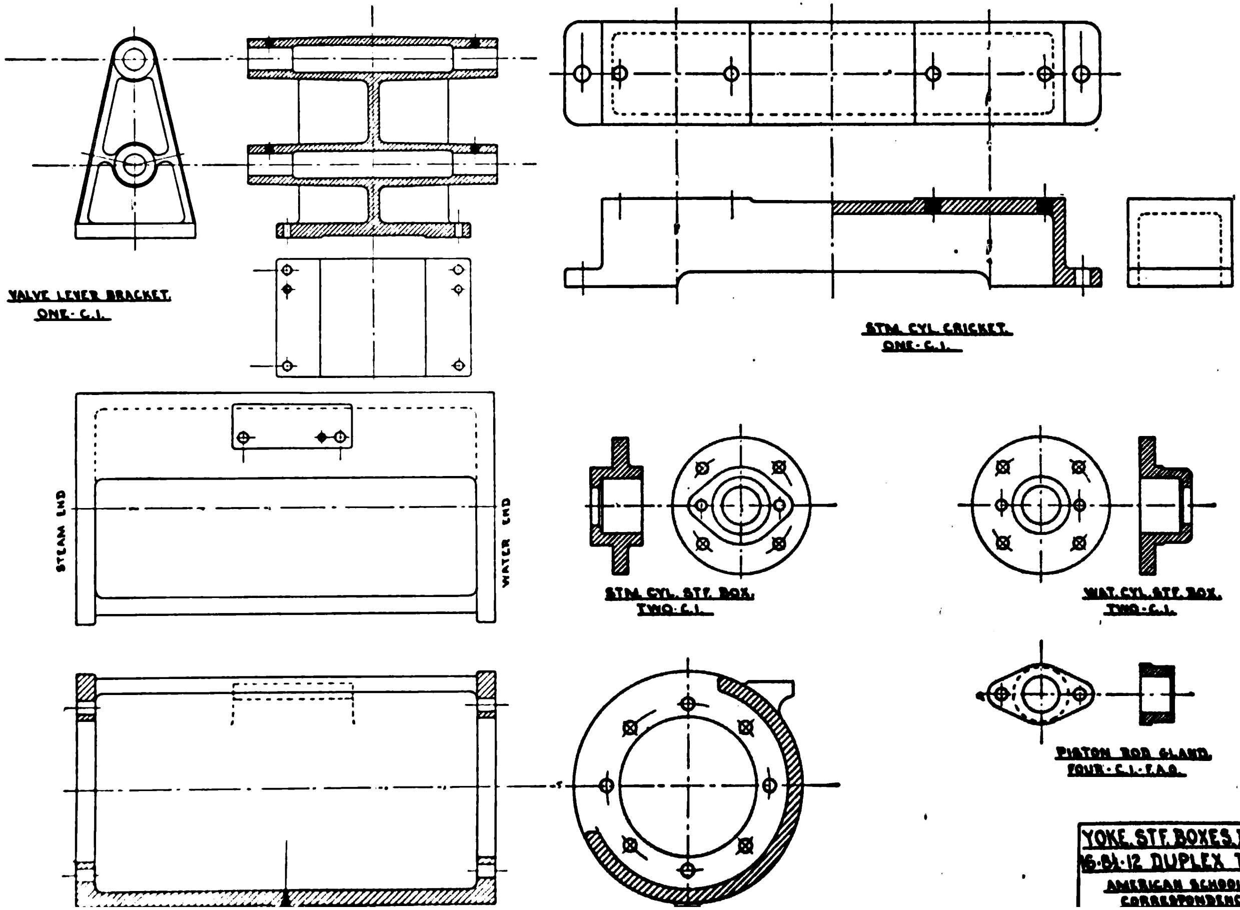
laid out before developing the cross-section of the valve bracket.

The design of stuffing boxes for both steam and water ends, and the length of the yoke, should be determined next. A safe method of assuming clearance between the spool and the gland studs at the end of the stroke, is to imagine that the gland stud nuts have accidentally worked off the studs, so that they are about to drop. They are thus shown by dotted lines on Plate C. A good clearance, say $\frac{1}{4}$ inch to $\frac{1}{2}$ inch, is then allowed, and the gland drawn in. The length of the gland is determined by the number of rings of packing necessary in the stuffing box; it is usually provided that the gland may compress the packing to about one-half its original depth before bringing up against the face of the box. Packing $\frac{5}{8}$ inch square will do for this size of piston rod, hence the faces of the yoke are easily determined, and its detail, with the stuffing boxes, proceeded with as on Plate L. The length of yoke may be brought to an even figure; and proceeding on the above plan the length can be conveniently made in even inches without any fractions; viz., 28 inches.

It will be noticed that the stuffing-box flanges serve to center the yoke in line with the steam and water cylinders. This is a desirable feature of construction, and forms a simple and easy method for lining up the steam and water ends.

Plate K. Valve Motion Details. The piston-rod levers on this plate are specified to be steel forgings. Forgings of this kind are expensive, but are light, neat and reliable for the important service which they have to perform. Castings, whether steel or iron, are much cheaper, and perhaps more commonly used for this detail. When sound they are equally serviceable, though of more clumsy proportions; but the danger in castings of this form is the existence of hidden flaws or pockets, which frequently occur at the points where the hub or the fork joins the arm. These flaws cannot be readily detected from the outside, and breakage may occur at some critical time, when the disability of the pump may be a serious matter.

The use of shade lines is illustrated on this plate. The increased artistic effect is noticeable, but it would seem that absolute clearness would still exist, even if shade lines were not used.



YOKE, STF. BOXES, BKT. ETC.
16·8½·12 DUPLEX PUMP.
AMERICAN SCHOOL OF
CORRESPONDENCE.

It will be noticed that on the detail of the "link pin" two of the dimensions have a short "wavy" line beneath the figures. This is one of the several ways of indicating that the dimension is "out of scale." Some draftsmen use a straight dash beneath the figure; some draw a circle about it; some print after the figure, "out of scale." Although workmen are not allowed to scale drawings, but are required to "work to figures only," yet for general safety's sake, and for the sake of the draftsmen who consult the drawings frequently, attention must be called to any variation of the figure from the measured distance on the drawing. Nothing makes a workman, or any one else who reads a shop drawing, lose confidence in it more quickly than to discover that it does not "scale"; but when no indication exists that the draftsman himself is aware of it, then every dimension is viewed with doubt and hesitation, and the drawing becomes practically worthless.

Dimensions seldom should be out of scale; but if they are, through error or necessary change, a carefully worded note should be added.

Molding and Machining. No special features of molding or machining are noteworthy on Plate K.

Plate L. Yoke, Stuffing-boxes, Bracket, etc. Having worked up the layouts of Plates C and D, the student has enough information to proceed with Plate L. This, like Plate G, is without dimensions, the student's work being to make the drawing and fill in the necessary shop data.

The valve-lever bracket is bolted down to its lug on the yoke through holes larger than the bolt, thus permitting slight adjustment. When the proper location is determined, the bracket is positively fixed in position by two dowels, $\frac{1}{2}$ inch in diameter. The holes in both bracket and yoke are drilled through both pieces at the same operation. This very common method of fixing bolted parts of machinery in absolute position not only assures firmness, but also in case of removal, permits the part to be readily and positively replaced in its exact original position.

If possible, the steam cylinder cricket should be of such height that the stone or brick work upon which it rests shall be at the same level as that beneath the water cylinder. The tapped holes in the top surface receive bolts from the cylinder foot. These bolts are often used only for shipping purposes, the cylinder foot when the pump is set up being allowed to slide freely on the cricket, thus permitting free expansion and contraction. In such cases the water end is rigidly fastened to the foundation by holding down bolts.

Molding and Machining. The valve lever-bracket would most naturally be molded with the axes of the shafts vertical, the parting line of the mold being the center line of the middle web. This makes quite a long "draw" for the shaft bosses, but the ample taper on the outside overcomes this difficulty. The space between the side webs leaves its own core. The shaft cores stand on end in the mold, which is the best position for strength and stability.

Another method is to have the parting line of the mold on the vertical center line of the bracket, as shown in the end view. In this case the bracket would be cast on its side, and cores must be set for each side of the middle web. The shaft cores are set as easily as before, but in this case lie flat. As with the steam chest, each method has its advantages, which depend largely upon existing conditions. As cored work is generally avoided whenever possible, the first method would probably be chosen.

The shaft bosses are "chamber-cored," to save labor in boring, the bearing surface for the shaft being only a short distance at the ends. The chamber-core diameter should be enough larger than the shaft so that by no possibility can the cutter run into the rough scale, even if the hole be bored slightly out of line. If it should do this, the labor of caring for the cutters more than offsets the attempted saving of labor.

The yoke is simply a barrel open at each end, and with a piece cut out of its side. The inside evidently must be cored out, and the core is satisfactorily supported at the ends on its horizontal axis. The parting line of the mold may be either the vertical or horizontal axis of the end view, the only difference being that in one case the ledge for the valve bracket will "draw," and in the other case it must be loose on the pattern and "pulled in" after the main pattern is drawn.

The cricket and stuffing boxes present no difficulties. The bore of the stuffing boxes and glands should be from $\frac{1}{32}$ inch to $\frac{1}{16}$ inch larger than the rod, to allow the fit to be entirely between the rod and the packing.

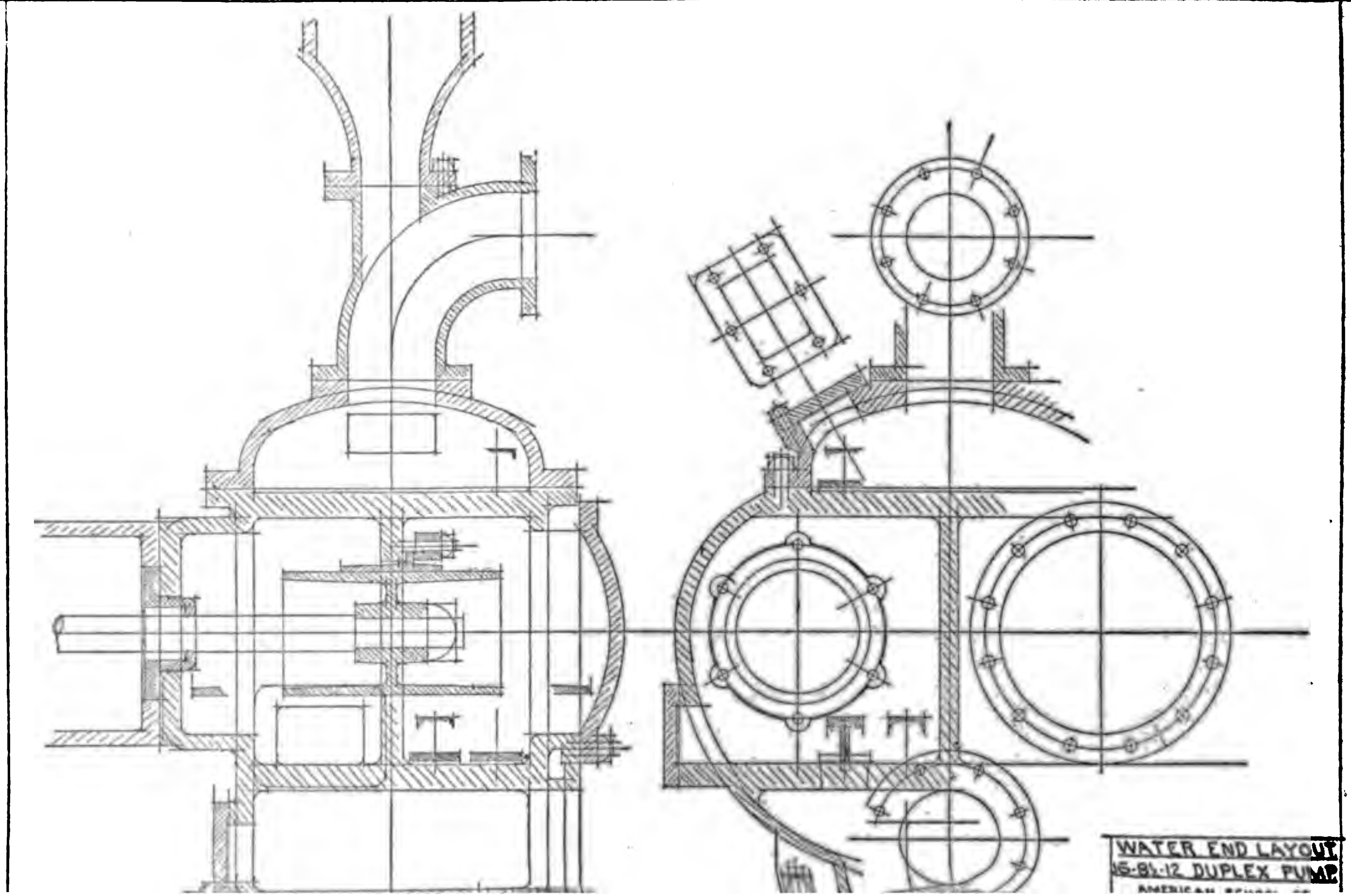
The horizontal boring machine with a double facing head is adapted to boring and facing the yoke flanges. The drilling is accomplished as before by templet or jig.

Attention is called to the tapped holes for oil or grease cups on the valve-lever bracket. The holes on the lower boss cannot be drilled strictly as shown, because the drill shank will not clear the upper boss. They should be swung around the boss at such an angle as will allow the drill to clear. This is a good instance of the common error of drawing details which cannot be made, and constant watch must be kept to avoid such mistakes.

Plate B. Water End Layout. As in the preceding work, Plates H and I being given in full detail offer a good start for the development of the water cylinder, which is the purpose of Plate B. As before, work should begin at the inside and progress outwards. Thus the piston rod with its nut should be drawn first, the hub of the plunger built around it, then the plunger barrel, the bushing, and ring to clamp the bushing. The limits of the plunger travel should be sketched in, and the valve outline shown in order to determine clearances. The progress of Plate B is on exactly the same basis as that stated in detail for the steam cylinder layout; hence it need not be repeated.

The points controlling the design of the water end must, however, be studied to enable the student to work intelligently. The fit of the rod into the plunger hub is loose, $\frac{1}{16}$-inch play being allowed, in order to permit the plunger to be guided solely by its bushing, and thus be independent of any change of alignment of the piston rod.

The relative length of plunger and bushing should allow the end of the plunger to overrun the edge of the bushing at the termination of the stroke, to prevent the formation of a shoulder. The bushing is made of brass because of the better bearing of the two dissimilar metals, brass and iron. Of course there is no lubrication except the water, and the dissimilar metals tend to "cut" less than if both were alike. The brass bushing also prevents the plunger from "rusting in" in case of long periods of


WATER END LAYOUT
15-8½-12 DUPLEX PUMP
AMERICAN SCHOOL OF

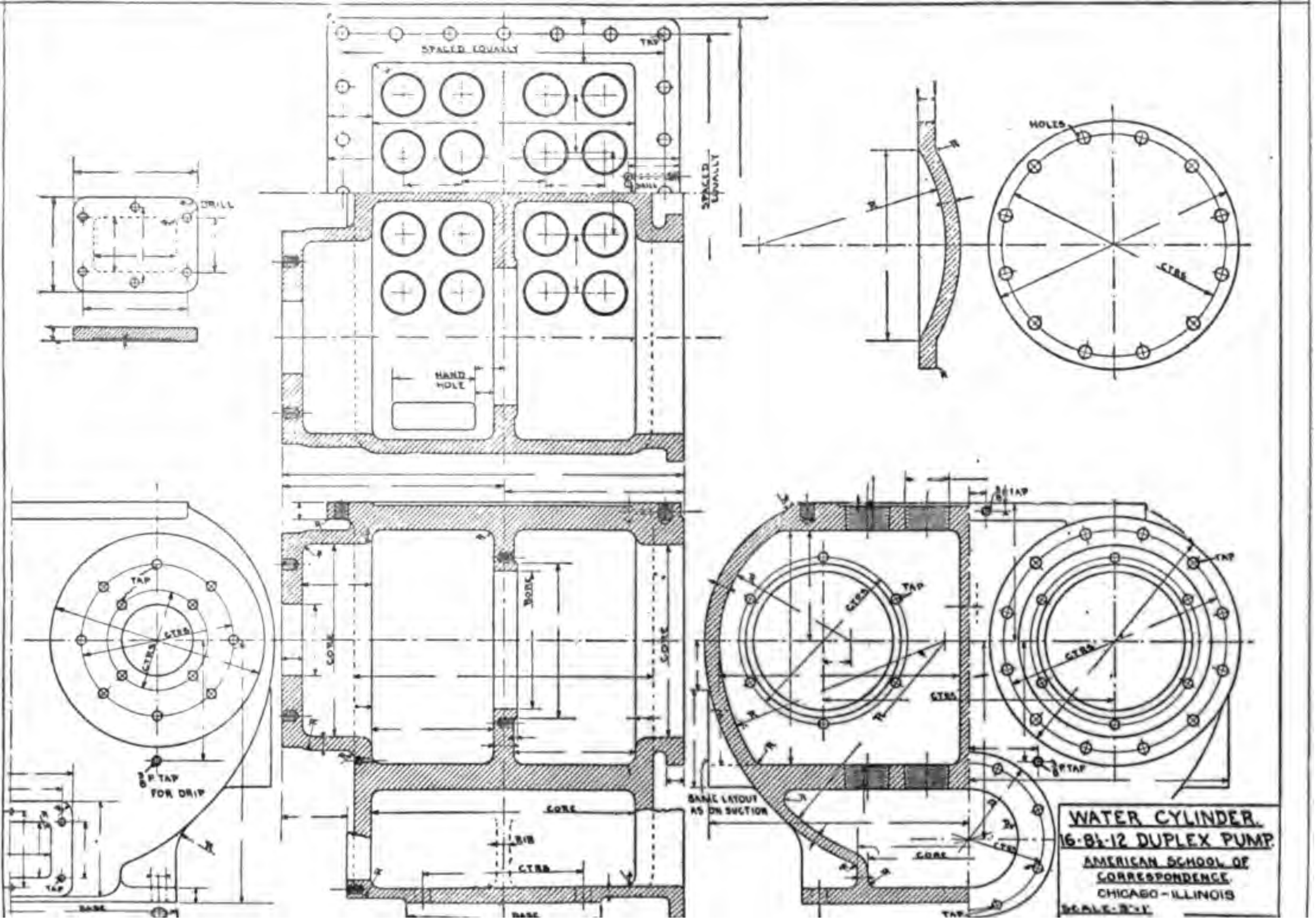
disuse. The bushing being of expensive material is made as light as possible, hence it has no stiffness of its own. Therefore it is reinforced by a deep cast-iron ring, which also takes the bolts and clamps the bushing tightly to its ground seat. These stud bolts are usually made of "tobin bronze," a rust-proof material, possessing strength almost as great as that of steel. This arrangement permits ready removal of the bushing when necessary.

As the parts of the common pump valve illustrated in detail on Plate H must be often replaced during service of the pump, provision must be made for unscrewing the stem and substituting a new one. This must be done through the hand holes provided on the cylinder. The lower valve deck must be located so that the inner valves when unscrewed will not strike the clamp ring. As shown in Plate B the clearance is pretty small, almost too small, but as it affects only two valves, it will probably cause no inconvenience. No hand holes are necessary for the end chambers, as access to the valves is had by removing the outer heads. The upper deck may be placed at a height giving sufficient clearance to allow the upper nuts of the clamp ring to be unscrewed with a socket wrench from the end of the pump. These decks are subjected to a severe pounding from the pulsations of the pump, and should be amply strong; 1¾ inches is deemed thick enough for this case.

The middle transverse wall may be 1½ inches thick and the middle longitudinal wall a little thinner, about 1¼ inches. With high pressures these walls, being flat surfaces and the valve decks likewise, are likely to fracture under the heavy pounding. To avoid making them excessively heavy they are often strongly ribbed, either on the inside or outside, usually the former.

The curving side walls are of better form to withstand pressure, and need not be as thick, 1 inch being sufficient. This can be decreased to ¾ inch in the suction passage below the deck, where little pressure exists.

The outer head is also considered strong enough at 1 inch thickness, on account of its curved shape. It requires ⅞-inch studs. Studs are preferred to tap bolts in this case, as in all other similar cases, on account of the frequent unscrewing of the nuts for purpose of removal. One or two unscrewings of a tap bolt in cast


WATER CYLINDER.
16·8½·12 DUPLEX PUMP.
AMERICAN SCHOOL OF CORRESPONDENCE.
CHICAGO - ILLINOIS
SCALE - 3" = 1'
SPACED EQUALLY
TAP
DRILL
HAND HOLE
HOLES
CTRS
R
CORE
BORE
RIB
BASE
TAP
⅜" P. TAP FOR DRIP
⅜" P. TAP
SAME LAYOUT AS ON SUCTION

iron will destroy the tightness of the thread, while the stud, being steel, stands the wear better.

The valve seats are taper screwed into the deck; they are sometimes forced in on a plain taper fit. They are located as closely as strength of the deck between the holes will permit. It is not well to place the edge of the valve closer than ½ inch from the cylinder walls. The valve holes in the lower deck should be in line, or nearly so, with the holes in the upper deck, in order to allow the shank of the mill to pass through when milling the lower holes.

The suction opening is 7 inches in diameter, 12½-inch flange, 10½-inch bolt circle, ¾-inch tapped holes.

By means of the hand hole at the end of the suction passage, any dirt which may have been brought in through the suction pipe may be removed.

The water cylinder cap, discharge ell and air chamber may be laid out from the detail Plate I, and the student must do this to see that the parts actually go together properly.

With the foregoing discussion the student should be able to produce Plate B, which is the preliminary step to the detail drawing of the water cylinder as shown on Plate J.

Plate J. Water Cylinder. The water cylinder is, perhaps, the most complicated detail that the student will meet in this set of plates. Fundamentally, it is simply a box with curved sides, divided by the several walls into five compartments, each of which communicates with the outside by a round nozzle or flange. If this basic idea be kept constantly in mind, the student will have no trouble in building up the detailed design.

This fundamental conception of a complicated piece is a very important idea, and should be developed carefully by the student. It is one of the great secrets of good design, both from an artistic and a commercial standpoint. We often see a machine which seems to begin anywhere and end nowhere; it appears to be a miscellaneous collection of bosses, lugs, ribs and flanges. There is no general prevailing shape to the structure, no harmony of the lines. This is because the designer, if he may be so called, did not have the fundamental notion of shape, to which all minor details should have been subordinated. He simply grouped parts together, without considering the fundamental structure.

In this water cylinder the box is the basic part of the structure, and its lines must be first developed; they should be designed to convey a smooth, regular and consistent surface to the eye. Then the nozzles and flanges may be added as subordinate parts; they will merely interrupt, but not destroy, the prevailing outline of the box. The dotted lines in the cross-section views of Plate J show the general shape behind and beneath the nozzles.

The hand holes are the same as on Plate I, and the detail of the cover should specify the number required for both places.

Provision for draining the four chambers of the water cylinder is made by the $\frac{3}{8}$-inch pipe tap holes at the lower deck, and the cap, likewise, by the single hole at the upper deck. Drip cocks are screwed into these holes.

The holding-down bolts should not be less than 1 inch diameter; $1\frac{1}{4}$ inch would perhaps be better; and the holes in the foot should be drilled at least $\frac{1}{8}$ inch large.

Dimensions. It will be noticed that this plate has dimension lines, but no figures. This is because the cylinder is rather difficult to figure, and it is desired to guide the student in arrangement of the figures without lessening the benefit of his study of them. Special attention should be paid to this feature of the plate. Notice that although space for dimensions is restricted, a clear opening is always found for the figures; and when one view seems to offer no space for a figure, another view gives the desired opportunity.

No finish marks or titles are shown on this plate, these being left entirely to the student for insertion.

Molding. The centers of the curves for the sides being on the main horizontal axis of the nozzles, the cylinder, if molded to be cast vertically as shown, will draw readily both ways from this line. The exceptions to this easy draw are the foot, suction nozzle and flange, and hand-hole boss. On account of the inside of the cylinder being cored, these pieces if made loose on the pattern have ample space to be "pulled in" after the main pattern is withdrawn.

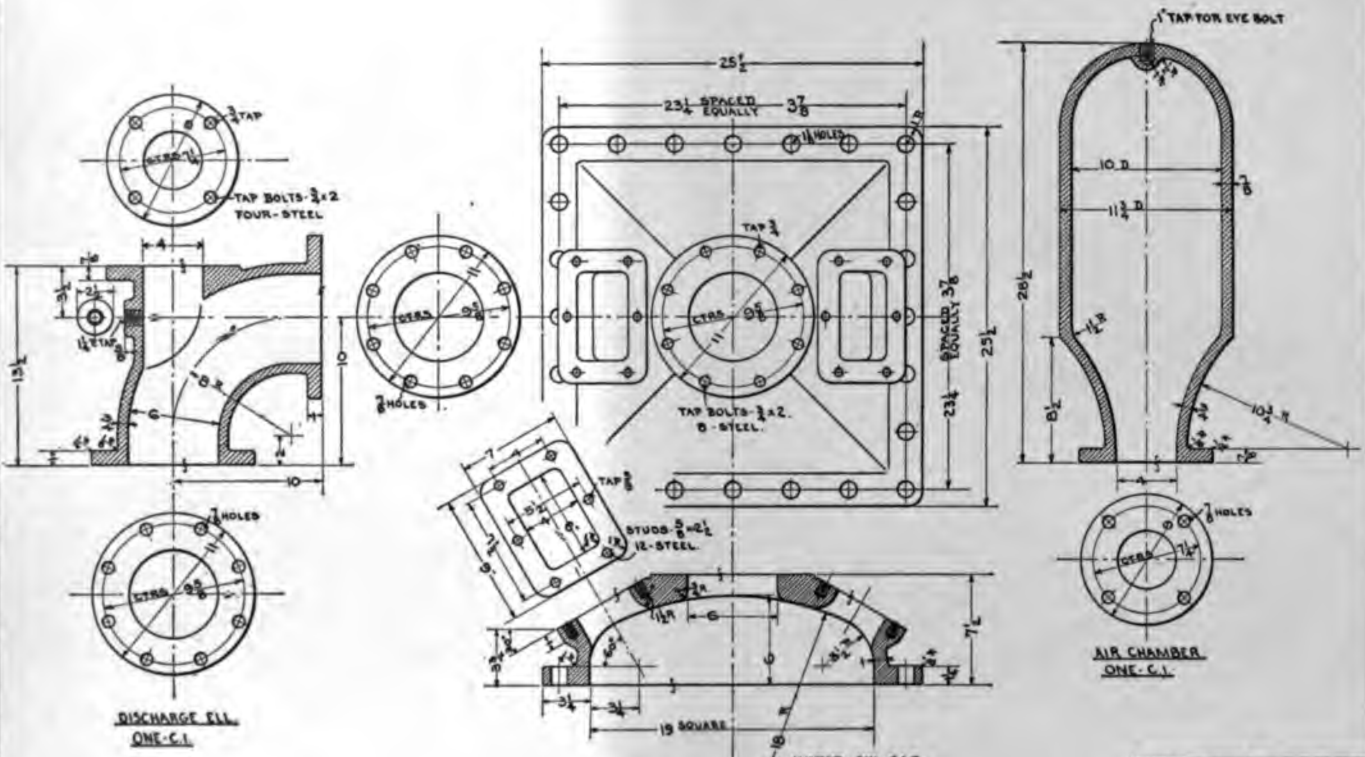
The suction passage below the deck communicates with the main core through the valve holes, hence it may be supported from the main core. This involves some difficulty, however. If a three-part flask be used, and another parting established at the center of the suction flange, in addition to the previous one, the problem becomes much simplified.

It is desirable to make the four chambers of the cylinder alike in general proportions. It is then possible to make a single core-box, and by the use of loose pieces change the length of the nozzle cores and transpose from right to left, thus saving labor on the pattern. This, however, multiplies the loose pieces on the pattern. The many pieces are likely to become lost and make frequent repair necessary. Hence it is not always wise to use a single core box too much, and good judgment is required to fix the limit.

Machining. Special double horizontal boring machines are now in common use for such cases as this water cylinder. The centers are made adjustable, so that within limits any distance between piston-rod centers can be met. The advantages of double boring are, of course, most obvious for a considerable number of duplicate cylinders.

It will be noticed that the face of the suction flange is carried out flush with the cylinder head face. This affords opportunity for finishing all the end surfaces at a single setting of the tool, whether the work be done on the rotary or reciprocating planer. This same point might have been observed on the small hand-hole boss at the other end of the cylinder, but the advantage gained did not seem to warrant extending the " reach " through the hand hole.

Plate I. Water Cylinder, Cap and Air Chamber. For a water cylinder cap of this size, the most difficult problem is to find room for the hand-hole bosses. A hand hole 4 inches × 6 inches is about as small as can be used, and this calls for a flange at least 7 inches × 9 inches. These are the proportions shown on the plate, and since the boss overhangs the bolts in the main-cap flange, it must be cut away underneath to clear the nuts. If three stud bolts are used on each side, this overhang also requires that the nut be " fed on "; that is, screwed on little by little as the end of the stud protrudes above the flange when the cap is being lowered into place. This is an awkward process, but is sometimes necessary.



WAT. CYL. CAP'S & AIR CHAMB.
16-8½-12 DUPLEX PUMP
AMERICAN SCHOOL OF

The discharge ell should have an easy bend; usually the radius is somewhat more than the outside diameter of the pipe, in this case 50 per cent greater. It is customary on this piece to provide an opening for the attachment of a relief valve as shown, $1\frac{1}{4}$-inch pipe tap. This valve can be set to open at a desired pressure, so that the water end may be relieved in case of accidental excessive pressure.

The air chamber provides an air cushion for the water to make the delivery more constant, and take the shock which would otherwise come with hammer-like force and full intensity upon the cylinder. Being placed at the highest point of the water end, air will naturally tend to collect in the air chamber and keep it charged. In some cases, however, a special charging device is necessary.

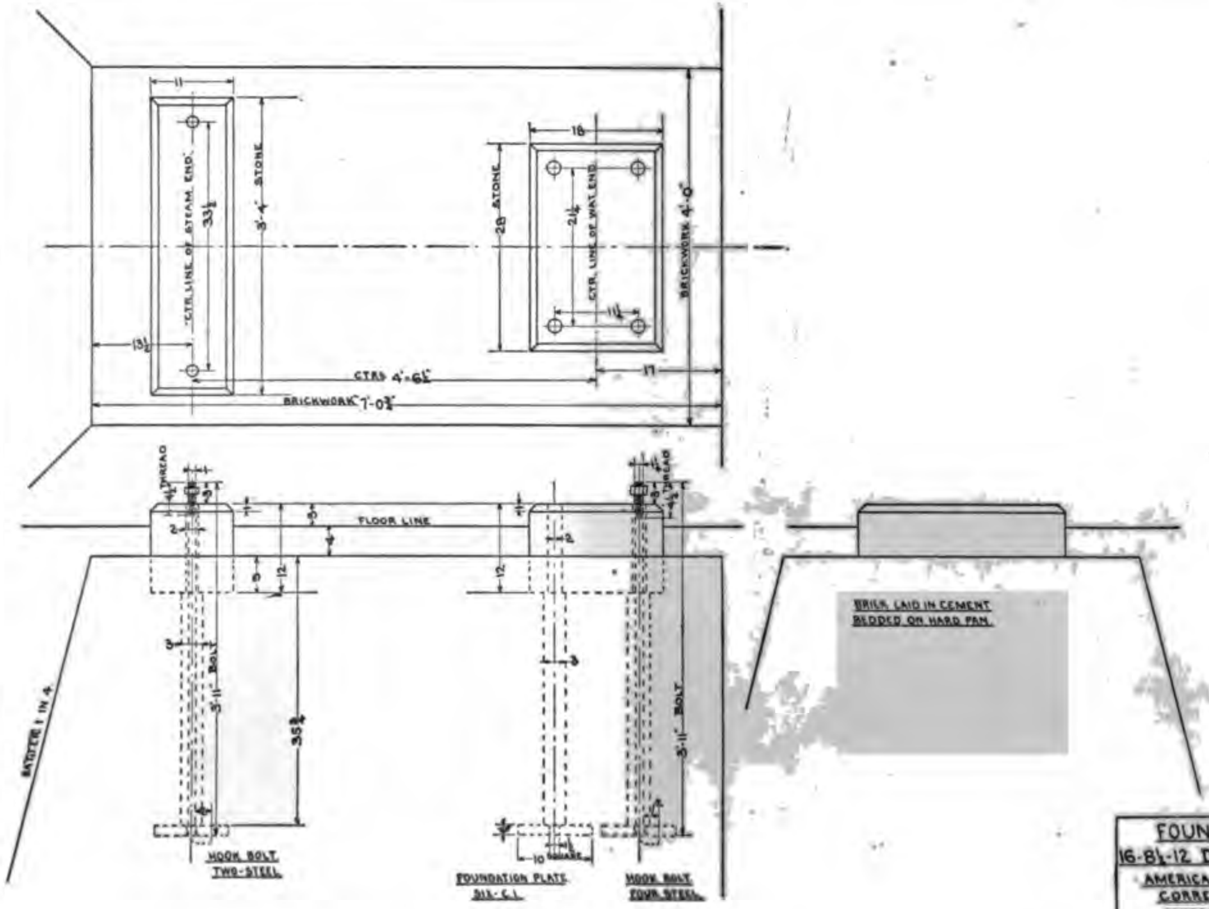
Molding and Machining. The hand holes being at an angle will not "draw." Hence cores must be set for these openings at least, and it may be desirable to core out the whole inside of the cap for the sake of keeping the pattern in good shape by making it solid. Otherwise it is easy to let it leave its own core.

The overhang of the hand-hole bosses requires loose pieces for the overhanging part. They are "pulled" in after the pattern is drawn.

The molding and machining which are further required on details of Plate I are simple, and require no special discussion.

Plate H. Plunger and Valve Details. This plate is noticeable for illustrating a method of drawing details not used elsewhere in this set of plates. On the other plates each piece is separately detailed. On Plate H the details of the valve, cover, seat, stem and spring are shown assembled, and dimensioned without separation. This is an allowable method when clearness is not sacrificed, but it is usually found desirable only with simple construction. It concentrates parts on the drawing, and probably saves some time, besides showing the workman just how the parts go together. The only test which the student need to apply in this, as in any method of detailing, is the test for absolute clearness.

It is believed in the case of the valve as shown that the details are completely illustrated without sacrificing clearness. Special care in putting in dimensions is of necessity required.



FOUNDATION
16-8½-12 DUPLEX PUMP
AMERICAN SCHOOL OF
CORRESPONDENCE.
CHICAGO - ILLINOIS
SCALE-1½"=1'.

The valve stem can be unscrewed either with a socket wrench on the inside or an ordinary fork wrench on the outside.

The seat, after being screwed to position in the deck, is often faced off, to true up any distortion caused by screwing in.

The valve itself, of rubber, can be bought of any desired grade of hardness. The specification for any given set of valves depend upon the quality of the water, the pressure and the general service of the pump.

Molding and Machining. By reason of the simple nature of the parts on this plate, the molding and machining is left entirely to the original consideration of the student.

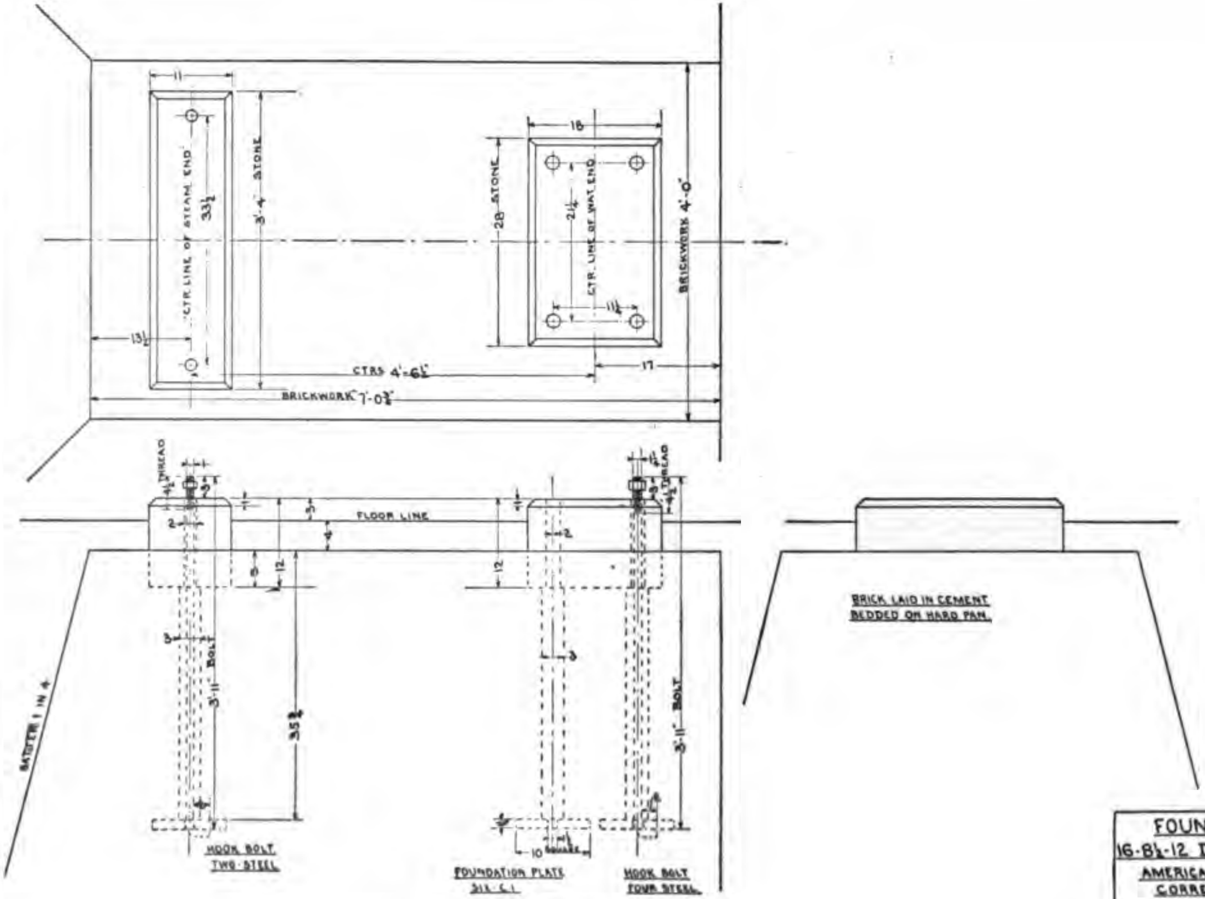
Plate M. Foundation. Pumps are often set directly upon a foundation of brick, but it makes a better job to bed stones, with surfaces dressed plane and true, into the main foundation, and rest the pump feet upon these stones. The simplest form of holding down bolts are shown on Plate M, a plain hook at the lower end, pulling up against a flat cast-iron plate, to distribute the pressure into the brickwork. These plates are of course bedded, and the bolts set as the foundation is built up. As the subsequent courses are laid some little space is left around the bolts, which may be afterwards filled with cement, thus making the bolts rigid with the foundation.

The water end of the foundation has no batter, because the suction pipe often drops vertically down from the end of the pump, and clearance is therefore necessary.

The floor line is placed 4 inches above the brickwork, to allow for the usual 1-inch top floor and 2-inch plank beneath, and still have a space left for shims to level the floor.

Plate N. General Drawing. This is an example of a plain, everyday shop drawing, to show the relation of parts and the extreme space occupied by the pump. A great deal of time can be needlessly wasted in producing a drawing of this character, by trying to make too faithful a picture. For example: If all the bolt heads were put in, it is safe to say that several hours' extra time would be required for this one item alone. But the drawing would be no better for shop use. Hence all bolt heads and nuts have been left out, except when necessary to show clearance.

Shade lines have been put on for no special reason except



FOUNDATION.
16-8½-12 DUPLEX PUMP.
AMERICAN SCHOOL OF
CORRESPONDENCE.
CHICAGO - ILLINOIS
SCALE-1½"=1'.

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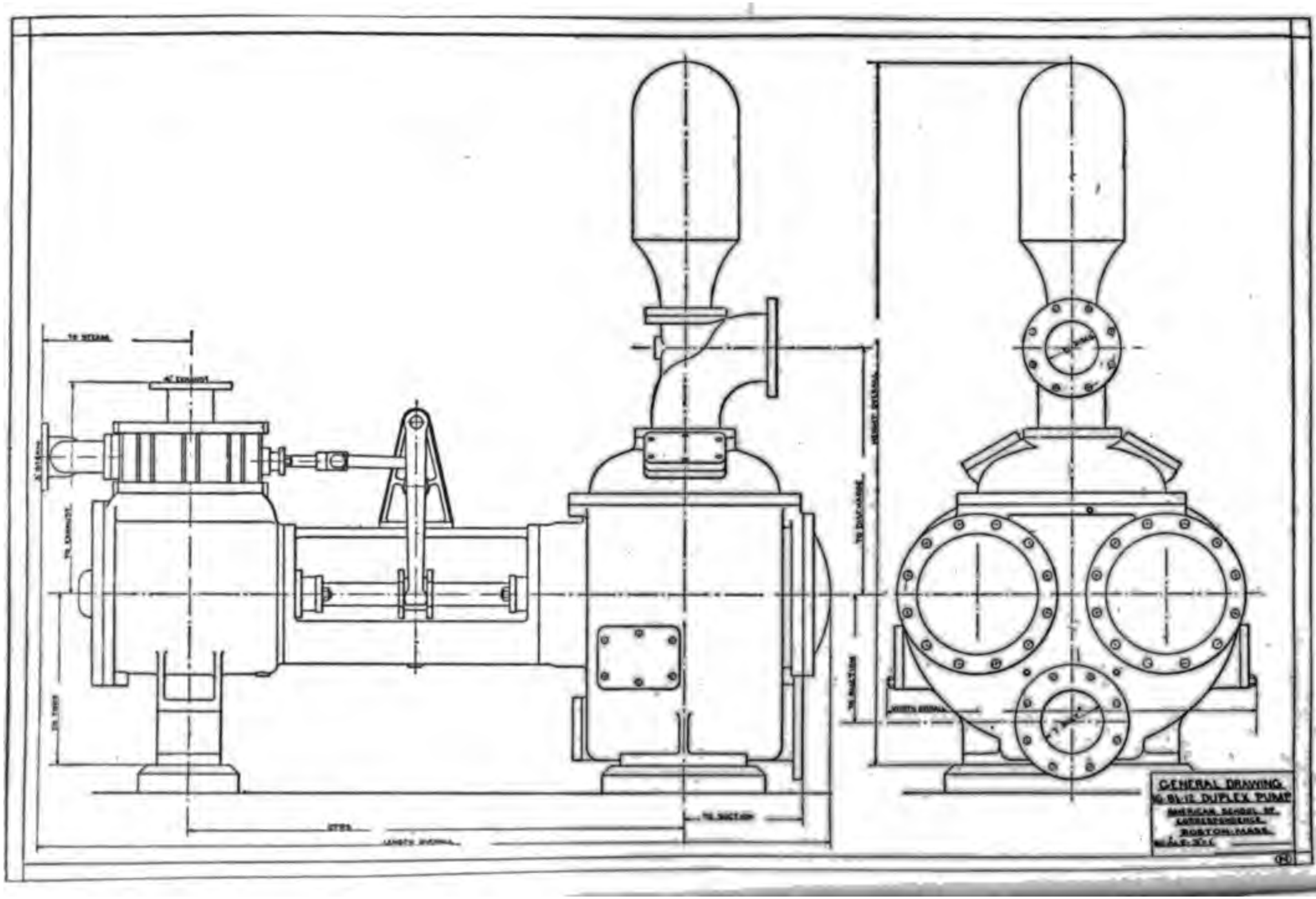
ASTOR, LENOX AND
TILDEN FOUNDATION


TO STEAM
4" EXHAUST
3" STEAM
TO EXHAUST
TO FEET
STROKE
LENGTH OVERALL
TO SUCTION
TO DISCHARGE
HEIGHT OVERALL
TO SUCTION
WIDTH OVERALL
GENERAL DRAWING
16·8½·12 DUPLEX PUMP
AMERICAN SCHOOL OF CORRESPONDENCE
BOSTON, MASS.
SCALE 3"=1'
20

that if they are desirable on any drawing they are especially desirable on a general drawing, where one part overlaps another, as they make it easier to pick out and separate one surface from another. Some lines are shaded in this drawing which are not strictly sharp edges. It is held, however, that the rounding of a corner ought not to destroy its character as an edge casting a shadow, and such lines are treated accordingly.

An assembled or general drawing of this character should be laid out strictly from the dimensions shown by the details. It thus serves a valuable purpose in checking up figures, and showing whether or not the parts will go together. The method or character of the work in no respect differs from that suggested for the detail drawings.

If a scale of 3 inches = 1 foot be used, the size of sheet must be 24 inches × 36 inches. The student, however, will perhaps find it easier to use a scale of $1\frac{1}{2}$ inches = 1 foot, in which case the ordinary size, 18 inches × 24 inches, will suffice. For such a small scale it will be found undesirable to attempt to put in any very small fillets and corners, although those that can be readily handled by the ordinary bow pen ought not to be omitted. As a matter of fact, the expert draftsman either leaves the corners sharp, as suggested, or puts in the smallest curves freehand.

Order Sheets. Any set of drawings is incomplete unless in connection with it a statement is made in tabular form of the complete make-up of the machine. An infinite variety of ways exists for making the specifications. Sometimes the tabulated data are placed on the general drawing. Most often, however, printed blanks are provided, usually of bond paper, arranged with special reference to the individual shop system and methods of handling work; these blanks are filled in by the draftsman, indexed and filed as a part of the set of drawings. They can be blue printed for use in the shops the same as a drawing. From these sheets stock is ordered, checked off, and watched in its process of manufacture.

Order sheets are indispensable in any well-ordered shop. Hence they are illustrated on pages 59, 60, 61 and 62 as the final step in the set of pump drawings. They are made as simple as possible, and are not intended to fit any special shop system. As previously stated, the exact form and method of classification can be determined only when the shop conditions are known.

The student, having carefully followed through the preceding pages, must not think that he is master of pump construction, for even the type illustrated has been but touched upon. The object of the detailed discussion is to get the student in close touch with the spirit of construction, to make his drawings real serious work. It is hoped that the student will work just as though a machine were to be built from his drawings, and built to sell at a profit. Only in this way can advanced work in mechanical drawing be of benefit to him, for after becoming expert in the use of the instruments, no other advance is possible except advance in *thought*.

DATE.
MAY 20, 1902.

AMERICAN SCHOOL OF CORRESPONDENCE
AT
ARMOUR INSTITUTE OF TECHNOLOGY
CHICAGO, ILL.

TYPE.
INSIDE PLUNGER.

LIST OF CASTINGS
FOR
16–8½–12 DUPLEX PUMP.

No. Wanted.	Name.	Drawing No.	Patt. or Piece No.	Material.	Remarks.
2	Steam Cylinder	G		C. I.	R. & L.
2	Steam Cylinder Head	G		C. I.	
2	Steam Chest	F		C. I.	
2	Steam Chest Cover	F		C. I.	
2	Slide Valve	F		C. I.	
1	Steam Pipe	F		C. I.	
1	Exhaust Tee	F		C. I.	
2	Valve Steam Gland	F		C. I.	
2	Piston	E		C. I.	
8	Piston Pipe Plug, 1½″	E		C. I.	
4	Piston Packing Ring	E		C. I.	
2	Spool	E		C. I.	
1	Steam Cylinder Cricket	L		C. I.	
2	Steam Cylinder Stuffing Box	L		C. I.	
2	Water Cylinder Stuffing Box	L		C. I.	
4	Piston Rod Gland	L		C. I.	
1	Valve Lever Bracket	L		C. I.	
2	Yoke	L		C. I.	R. & L.
1	Short Rocker Arm	K		C. I.	
1	Long Rocker Arm	K		C. I.	
2	Valve Stem Link	K		C. I.	
1	Water Cylinder	J		C. I.	
2	Water Cylinder Head	J		C. I.	
3	Hand Hole Cover	J		C. I.	
1	Water Cylinder Cap	I		C. I.	
1	Air Chamber	I		C. I.	
1	Discharge Ell	I		C. I.	
2	Plunger	H		C. I.	
2	Plunger Bushing	H		Brass	
2	Clamp Ring	H		C. I.	
32	Valve Stem	H		Brass	
32	Valve Cover	H		Brass	
32	Valve Seat	H		Brass	
6	Foundation Plate	M		C. I.	

DATE. MAY 20, 1902.	AMERICAN SCHOOL OF CORRESPONDENCE AT ARMOUR INSTITUTE OF TECHNOLOGY CHICAGO, ILL.	TYPE. INSIDE PLUNGER.

LIST OF STEEL AND MISCELLANEOUS PARTS

FOR

16—8½—12 DUPLEX PUMP.

No. Wanted.	Name.	Drawing No.	Patt. or Piece No.	Material.	Remarks.
2	**Valve Steam Head**	**E**		**St.**	**Drop Forging.**
2	**Piston Rod**	**E**		**C. R. S.**	
2	**Valve Stem**	**E**		**St.**	
1	**Long P. R. Lever**	**K**		**St.**	**Forging**
1	**Short P. R. Lever**	**K**		**St.**	**Forging**
1	Upper Rocker Shaft	K		St.	
1	Lower Rocker Shaft	K		St.	
2	Rocker Arm Pin	K		St.	
2	Link Pin	K		St.	
1	Long P. R. Lever Key	K		St.	Drop Forging
1	Short P. R. Lever Key	K		St.	Drop Forging
2	Rocker Arm Key	K		St.	Drop Forging
32	Valve Spring	H		Brass wire	Spring Temper
32	Valve	H		Rubber	Medium

DATE.
MAY 20, 1902.

AMERICAN SCHOOL OF CORRESPONDENCE
AT
ARMOUR INSTITUTE OF TECHNOLOGY
CHICAGO, ILL.

TYPE.
INSIDE PLUNGER.

LIST OF BOLTS, NUTS AND PINS
FOR
16—8½—12 DUPLEX PUMP.

No. wanted.	Name.		Drawing No.	Patt. or Piece No.	Material.	Remarks.
24	Cylinder Head	Stud $\frac{7}{8}$ x $3\frac{1}{4}$	G		St.	
20	Steam Chest	Stud $\frac{3}{4}$ x $8\frac{3}{4}$	G		St.	
4	Valve Stem Gland	Stud $\frac{5}{8}$ x $4\frac{3}{4}$	F		St.	
8	Piston Rod Gland	Stud $\frac{3}{4}$ x 4	L		St.	
24	Water Cylinder Head	Stud $\frac{7}{8}$ x $3\frac{1}{4}$	J		St.	
12	Clamp Ring	Stud $\frac{3}{4}$ x $4\frac{1}{2}$	J		Tobin bz.	
24	Water Cylinder Cap	Stud 1 x $3\frac{1}{2}$	J		St.	
18	Hand Hole Cover	Stud $\frac{5}{8}$ x $2\frac{1}{2}$	J		St.	
12	Hand Hole Cover	Stud $\frac{5}{8}$ x $2\frac{1}{2}$	I		St.	
8	Exhaust Tee	Tap Bolt $\frac{5}{8}$ x $1\frac{3}{4}$	G		St.	
16	Yoke	Tap Bolt $\frac{3}{4}$ x 2	G		St.	
8	Steam Cyl. Stf. Box	Tap Bolt $\frac{3}{4}$ x $1\frac{3}{4}$	G		St.	
8	Steam Pipe	Tap Bolt $\frac{5}{8}$ x $1\frac{1}{2}$	F		St.	
4	Valve Lever Bracket	Tap Bolt $\frac{5}{8}$ x $1\frac{3}{4}$	F		St.	
4	Steam Cyl. Cricket	Tap Bolt 1 x $2\frac{1}{4}$	F		St.	
16	Yoke	Tap Bolt $\frac{3}{4}$ x 2	J		St.	
8	Water Cyl. Stf. Box	Tap Bolt $\frac{3}{4}$ x $1\frac{3}{4}$	J		St.	
8	Discharge Ell	Tap Bolt $\frac{3}{4}$ x 2	I		St.	
4	Air Chamber	Tap Bolt $\frac{3}{4}$ x 2	I		St.	
2	Hook Bolt (special)	1 x 3′—11″	M		St.	
4	Hook Bolt (special)	$1\frac{1}{4}$ x 3′—11″	M		St.	
1	Eye Bolt	Standard 1″	I		St.	
34	Standard Nut	$\frac{5}{8}$			St.	
44	Standard Nut	$\frac{3}{4}$			St.	
36	Standard Nut	$\frac{7}{8}$			St.	
26	Standard Nut	1			St.	
4	Standard Nut	$1\frac{1}{4}$			St.	
4	Standard Nut	2			St.	
8	Special Valve Stem Nut	1			St.	$\frac{3}{4}$ Thick
4	Piston Rod Split Pin	$\frac{1}{4}$ x 2	E		St.	
2	Spool Taper Pin	No. 10 Morse Taper	E		St.	4″ long
4	Valve Bracket Dowel Pin	$\frac{1}{4}$ x 2	L		St.	

DATE.
MAY 20, 1902.

AMERICAN SCHOOL OF CORRESPONDENCE
AT
ARMOUR INSTITUTE OF TECHNOLOGY
CHICAGO, ILL.

TYPE.
INSIDE PLUNGER.

LIST OF SPECIAL FITTINGS, WRENCHES, ETC.

FOR

16—8½—12 DUPLEX PUMP.

No. Wanted.	Name.		Drawing No.	Patt. or Piece No.	Material.	Remarks.
4	Drip Cock	⅛"	G			
1	Drip Cock	¼"	F			
2	Drip Cock	¼"	L			
4	Oil Cup	¼"	L			
5	Drip Cock	⅜"	J			
1	Relief Valve	1¼"	I			175 lbs. pressure
1	Standard Fork Wrench	⅝"				
1	Standard Fork Wrench	¾"				
1	Standard Fork Wrench	⅞"				
1	Standard Fork Wrench	1"				
1	Socket Wrench	¾"				12" handle
1	Valve Stem Fork Wrench					
1	Valve Stem Socket Wrench					

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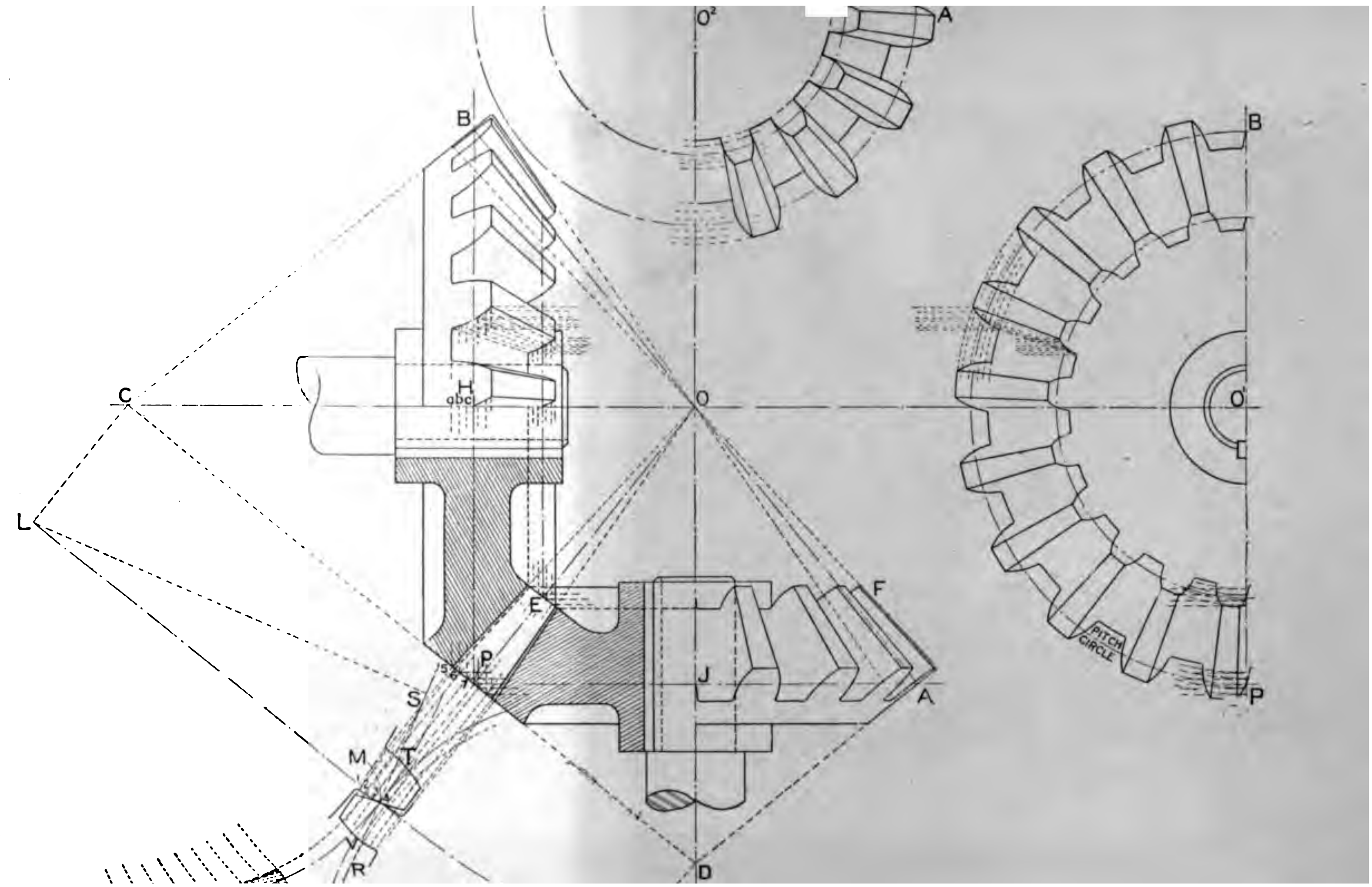
ASTOR, LENOX AND
TILDEN FOUNDATION


O²
A
B
B
H
abc
C
O
O
L
E
F
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MECHANISM

The study of mechanism is the study of the laws that govern the motions and forces in machinery. Pure mechanism deals only with the amount and kind of motions, without regard to the forces transmitted, and in this instruction paper only this branch of the subject will be considered. That is, we shall study how to proportion the parts to get the proper motions. Knowing this, the principles of machine design and strength of materials will teach us how large the parts must be to stand the stresses which come upon them.

A Mechanism is a group of parts so shaped and arranged that a definite motion of one part will give other definite motions to the other parts.

A Machine is a combination of mechanisms each of which may be doing a different kind of work, but the whole combination of mechanisms working together accomplishes some desired result. Take for example, a metal planer; the result which is to be accomplished is the planing of a piece of metal, but in order to do this, several auxiliary results must be accomplished. The table or platen, to which the metal is fastened must be moved back and forth, the tool must be fed forward after each chip has been cut, and various other motions produced. There are certain pieces in the planer whose sole work is the moving of the platen, and all these pieces taken together form one mechanism; in like manner, there are certain parts whose sole work is feeding the tool forward each time, and all these parts taken together form another mechanism. All the mechanisms when brought together form the machine.

MOTION.

An object which is changing its position is said to be in motion and an object which is not changing its position is at rest.

Absolute and Relative Motion. If a man is moving along in a sail boat without changing his position in the boat, both man and boat have what is usually spoken of as absolute motion, that is, they are both changing their position with respect to the earth and water around them. They both change their position in the same direction and at the same rate however, so that they are at rest with respect to each other. If now, the man should start to walk forward in the boat, he would change his position with respect to surrounding objects faster than the boat and he would have motion relative to the boat. We thus have two kinds of motion, absolute and relative; absolute motion being the motion of a body with respect to some fixed object, and relative motion being the motion of one moving body with respect to another moving body.

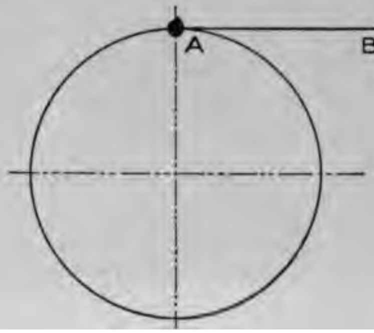


Fig. 1.

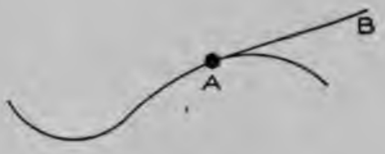


Fig. 2.

Since every object has more or less size and therefore can not be represented on paper as readily as can some particular point or line in the body, as far as possible in our study of the motions of bodies we shall consider points and lines, in place of the bodies themselves.

Velocity is the rate of motion. If a bullet travels through the air at the rate of one hundred feet in a second, it has a velocity of one hundred feet per second.

Direction of Motion. A point may have motion in a straight line, in a circle, or in any other curve. The tendency of any body which is in motion is to continue to move in a straight line unless caused to leave that path by some force applied to the body. The direction of the straight line in which a point is moving is called the direction of motion of the point. If an object is traveling in a circle, the direction of its motion at any given instant is the straight line tangent to the circle at the point where the object is at the given instant. For example, if the point A, Fig. 1, is moving around the circle, the direction of its motion, when in the position shown, is the line AB. In the same way in Fig. 2, if the point A is moving in the curved path, its direction when in the position indicated is the line AB.

By choosing a convenient scale, as one inch equals one foot, or one inch equals ten feet, etc., depending upon how large the velocities are with which we have to deal, the line may be drawn of a length that will represent the velocity of the point A. Suppose the circle, Fig. 1, to have a circumference of ten inches, and suppose the point A to be traveling around the circle at such a speed that it goes around once in five seconds; then, since it travels ten inches in five seconds, it has a velocity of two inches per second. Accordingly, if we draw the line AB two inches long, tangent to the circle at any given position of A, the line AB represents the direction and velocity of A at the instant under consideration. Of course, the direction of motion of a point which is moving in any path other than a straight line is constantly changing, but the direction in which it is moving at a given instant is the direction which it would take if the forces which constrain it to move in the curved path were removed at that instant.

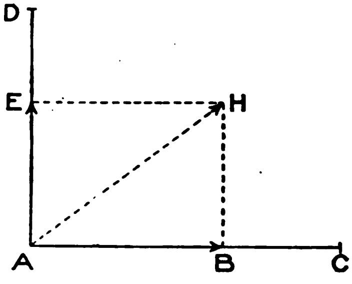


Fig. 3.

Composite Motions. In Fig. 3, let A represent a body lying on a table; suppose AC and AD are strings making a right angle with each other. First, let the string AC be pulled with such force that it will cause A to move one inch in the direction AC, in one second; then A will be at B at the end of a second, the line AB representing the direction and velocity of A when the string AC is pulled. Next, suppose the body to be back in its original position A, and that the string AD is pulled with such force that it will cause A to move $\frac{3}{4}$ of an inch in the direction AD in one second; then at the end of a second A will be at E, the line AE representing the direction and velocity of the body when the string AD is pulled.

Again, suppose both strings to be pulled at the same time, with the same force as before. Then the pull on AC will still cause A to move toward C with a velocity AB, and the pull on AD will cause A to move toward D with a velocity AE, so that at the end of a second the body will be at neither E nor B, but at some point H, whose position is at a distance BH from B, the line BH being equal and parallel to AE. The point H is also at a distance EH from E, the line EH being equal and parallel to AB. In other words, the path over which the body has moved is the line AH, which is the diagonal of a parallelogram whose sides are equal to AB and AE respectively. The lines AB and AE, which represent the velocities caused by the pulls on the respective strings, must be drawn to the same scale, that is, if the pull on AC causes a velocity of one inch per second and the pull on AD causes a velocity of $\frac{3}{4}$ inch per second, AE must be $\frac{3}{4}$ as long as AB.

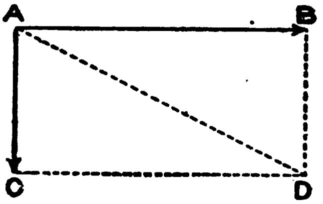


Fig. 4.

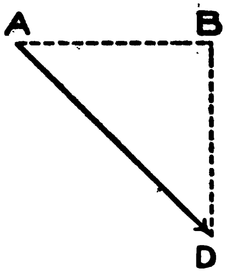


Fig. 5.

The velocities AB and AE are called *component velocities*, and the velocity AH the *resultant*.

Let us take another example. Suppose a ball is thrown toward the east with a velocity of ten feet per second, and the wind carries the ball toward the south with a velocity of five feet per second. Let us find graphically how fast and in what direction the ball is actually moving. Using any convenient scale, draw the line AB, Fig. 4, to represent ten feet, and the line AC to represent five feet at the same scale, AC being at right angles to AB, since south is at right angles to east. From C draw CD parallel to AB, and from B draw BD parallel to AC meeting CD at D; then AD, the diagonal of the rectangle thus formed, gives the direction and the velocity, at the same scale as before, of the actual motion of the ball.

The preceding process is called *composition* of velocities; that is, if we know the velocity of a body in two directions at right angles to each other, we can find from these the real velocity and direction of the motion. Quite as frequently we have given the real direction and velocity and wish to find the velocity parallel and at right angles to some given line. Thus, suppose we know that a ball is moving at a speed of one hundred feet per minute toward the southeast and we wish to know how fast it is moving towards the east. Draw the line AD, Fig. 5, to represent one hundred feet, at a convenient scale; then draw the line AB, making with AD the same angle that a line running southeast makes with a line running east (that is, 45 degrees). From D draw DB perpendicular to AB, meeting AB at B; the length of AB represents, at the same scale at which AD was drawn, the velocity of the ball in an easterly direction, and BD represents its velocity in a southern direction. This is called the *resolution* of velocities, the velocity AD being resolved into two components, one in the direction AB, and one perpendicular to this direction.

*EXAMPLES FOR PRACTICE.

1. If a steamer travels 91,200 feet per hour, what is the velocity in feet per second?

Ans. 25.33 feet.

2. If the piston of an engine moves at the rate of 12.5 feet per second, what is the piston speed in feet per minute?

Ans. 750 feet.

3. A steamer is moving eastward at a speed of 800 feet per minute and the wind and tide carry it north at the rate of 100 feet per minute. Find graphically how fast and in what direction the steamer is actually moving.

Ans. 810 feet per minute.

4. A ball is thrown, with a velocity of 50 feet per second, across a stream 100 feet wide. The wind carries the ball up stream 10 feet per second. How far up stream from the point at which the ball was aimed will it strike? Ans. 20 feet.

*NOTE. To be solved graphically.

5. A platform is set up at an angle of 30 degrees with the horizontal, and a weight is allowed to slide down the platform at a speed of ten feet per second. How long will it take the weight to get 10 feet below the point from which it started?

Ans. 2 seconds.

6. The horizontal component of the velocity of a body is 26 feet per minute. If the actual velocity is 52 feet per minute find graphically the vertical component.

Ans. 45 feet per minute (about).

7. A man is on a railway train which is moving at the rate of 25 miles per hour and walks toward the rear of the train at the rate of 88 feet per minute. How fast is the man actually moving?

Ans. 24 miles per hour.

Temporary Center of Revolution. In Fig. 6, let AB represent a bar that forms some part of a mechanism, and suppose that for the moment the end B has a velocity in the direction of and equal to BD, and that the end A has a velocity in the direction of and equal to AC. As the whole rod, for the instant, is moving as if it were revolving about a center, the actual velocities of the various points in the rod are proportional to their distances from the center. To find the center for the case shown, draw the lines AT and BT perpendicular to AC and BD, respectively, until they meet at T, which is the center about which the whole rod may be considered to be revolving. The velocities AC and BD cannot be chosen at random, but must be such that BF is equal to AE; that is, their components in the direction of AB must be equal.

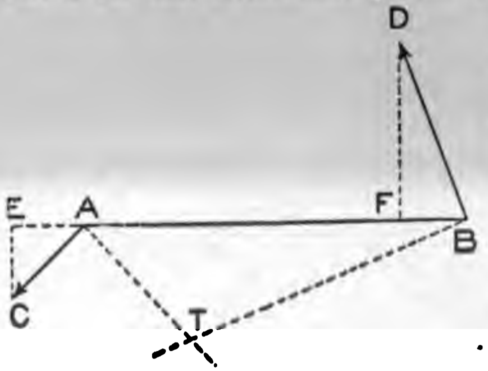


Fig. 6.

REVOLVING BODIES.

One of the most common motions which is found in machinery of all kinds is the motion of revolution, that is, the motion of a body turning around a center or axis. The axis may pass through the body itself or it may lie entirely outside the body. Fig. 7 is an example of the first case, where the cylinder is revolving about the shaft A, which passes through the center of the cylinder. Fig. 8 is an example of the second case where the block B is revolving about the shaft A.

The speed of revolution of a body is generally described by giving its number of revolutions per minute, which is abbreviated to R. P. M.

We will use the following abbreviations throughout this instruction paper: d=diameter; r=radius or distance of a point from the center about which it is revolving, and π (pronounced Pi) = 3.1416.

Let us consider a point C on the circumference of the cylinder in Fig. 7. For every complete revolution of the cylinder the point C travels through the air a distance equal to the circumference of the cylinder, or, since the circumference of a cylinder is 3.1416 times its diameter, the point C will travel 3.1416 times the diameter of the cylinder. Therefore the actual velocity through the air or **linear velocity** as it is termed, of a point on the circumference of a revolving cylinder is equal to the diameter of cylinder times 3.1416 times the number of revolutions in a unit of time.

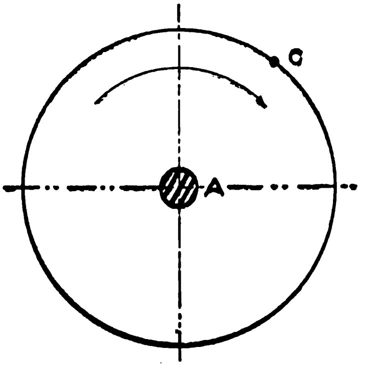


Fig. 7.

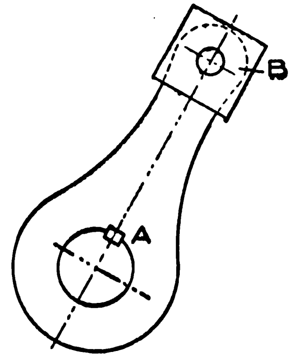


Fig 8.

If we assume a foot as our unit of distance and a minute as our unit of time, the above principle may be stated as a formula:

$$\text{Linear Velocity} = \pi\, d \text{ times R. P. M.} \qquad (1)$$

$$\text{or " " } = 2\,\pi\, r \text{ times R. P. M.} \qquad (2)$$

This will give the linear velocity in feet per minute and to use this formula the diameter or radius must be expressed in feet or fractions of a foot. If d or r is in inches, the linear velocity will be in inches. If linear velocity per second is desired, the number of revolutions per second must be used instead of R. P. M. From this formula we see that the linear velocity varies directly as the diameter or radius, and also directly as the number of revolutions.

The following examples will illustrate the use of the above formula:

If a fly wheel is 10 feet in diameter and makes 75 revolutions per minute, how fast is a point on its circumference moving? Using formula (1),

$$\begin{aligned}\text{Linear Velocity} &= \pi\, d \times \text{R. P. M.}\\ &= 3.1416 \times 10 \times 75.\\ &= 2356.2 \text{ feet per minute.}\end{aligned}$$

Therefore a point on the circumference of the fly wheel is moving at the rate of 2356.2 feet per minute.

Suppose that the center of the block B, Fig. 8, is at a distance of 18 inches from the center of the shaft A and that the arm turns around the shaft 60 times per minute. To find the linear velocity of the center of block B, we must first reduce the 18 inches to feet. Then,

$$\begin{aligned}\text{Linear Velocity} &= 2 \times 3.1416 \times 1.5 \times 60.\\ &= 565.49 \text{ feet per minute.}\end{aligned}$$

The same formula may be used to find the diameter or radius when the linear velocity and revolutions are given, or to find the revolutions when the linear velocity and diameter or radius are given. To do this, substitute the known quantities in the equation and solve by Algebra to find the unknown quantity. Let V = Linear Velocity.

Linear Velocity: $V = \pi d \times \text{R. P. M.}$

Diameter: $d = \dfrac{V}{\pi \times \text{R. P. M.}}$

Revolutions: $\text{R. P. M.} = \dfrac{V}{\pi d.}$

EXAMPLES FOR PRACTICE.

1. Find the linear velocity of a point on the rim of a fly wheel making 120 revolutions per minute. Assume fly wheel to be 7 feet in diameter. Ans. 2638.9 feet.

2. How many turns will a 6-foot wheel make while going one mile? Ans. 280.

3. A locomotive is running at the rate of 40 miles per hour. How many revolutions are the $6\frac{1}{2}$-foot drivers making per minute? Ans. 172.

4. The drivers of a locomotive are $5\frac{1}{2}$ feet in diameter. The crank pin is twelve inches from the center of the wheel. Find the linear velocity in feet per second of the crank pin if the engine makes 25 miles per hour. Ans. 13.32.

CYLINDERS AND CONES REVOLVING IN CONTACT.

When two cylinders are arranged to revolve upon parallel axes which are at a distance apart just equal to the sum of the radii of the two cylinders, their circumferences will touch along one line, and if both cylinders revolve and we assume that there is no slipping of one surface on the other, the surface velocities of their circumferences must be equal, that is, the linear velocity of any point on the surface of one would be the same as the linear velocity of any point on the surface of the other. Then, if in Fig. 9, we let S equal the surface velocity of the cylinders, C the radius of cylinder A, D the radius of B, M the revolutions per minute of A, and N the revolutions per minute of B, we can obtain the following equations by substituting these values in formula (2):—

$$S = 2\,\pi\,C \times M.$$
$$S = 2\,\pi\,D \times N.$$

and dividing the first by the second we have:

$$\frac{S}{S}=\frac{2\pi C\times M}{2\pi D\times N} \text{ or } 1=\frac{C M}{D N}$$

therefore $D N = C M$ or $D \times N = C \times M$.

According to ratio and proportion in Algebra,

$$\frac{M}{N}=\frac{D}{C} \qquad (3)$$

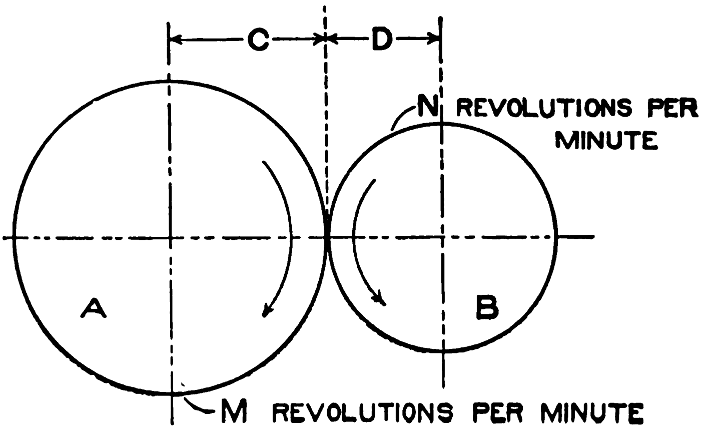


Fig. 9.

This may be stated as follows:—

$$\frac{\text{Revolutions of Driver}}{\text{Revolutions of Driven}}=\frac{\text{Radius of Driven}}{\text{Radius of Driver}}$$

That is, the numbers of revolutions are to each other inversely as the radii, and therefore as the diameters.

Two cylinders revolving in contact, without slipping, revolve in opposite directions; that is, if A revolves right-handed (like the hands of a clock), B will revolve left-handed. This is indicated by the arrows in Fig. 9.

The following examples will illustrate the method of calculation for speeds of cylinders, according to the preceeding discussion. Suppose a wheel A, 2 feet in diameter, is revolving with its surface in contact with the surface of another wheel B. A makes

25 R. P. M. Assuming that no slipping occurs between the surfaces of the two wheels, what must be the diameter of B in order that it shall make 75 R. P. M.? From the formula (3) we have

$$\frac{\text{Diameter of B}}{\text{Diameter of A}} = \frac{\text{R. P. M. of A}}{\text{R. P. M. of B}}$$

or

$$\frac{\text{Diameter of B}}{\text{2 feet}} = \frac{25}{75}$$

$$\text{Diameter of B} \times 75 = 2 \times 25$$

therefore Diameter of B $= \frac{2}{3}$ feet $= 8$ inches.

The same principles apply to cones which are revolving in contact. Let Fig. 10 represent the side view of two right cones which are in contact along the line EF, which is an element common to both. Then,

$$\frac{\text{R. P. M. of A}}{\text{R. P. M. of B}} = \frac{FG}{FH} \qquad (4$$

That is, their revolutions are to each other inversely as the diameters of their bases. If the angles OEF and O'EF are known, instead of the diameters of the bases, the ratio of the number of revolutions may be found from the following trigonometric formula:

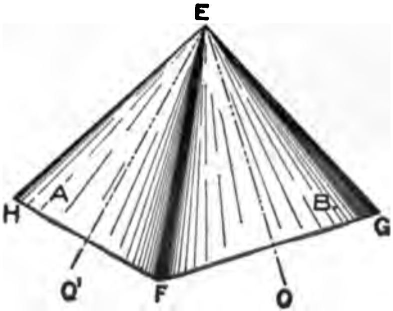


Fig. 10.

$$\frac{\text{R. P. M. of A}}{\text{R. P. M. of B}} = \frac{\text{Sine of angle OEF}}{\text{Sine of angle O'EF}} \qquad (5)$$

If the angle between the axes OE and O'E is given and it is desired to find the relative sizes of the two cones whose revolutions shall have a given ratio, the angles OEF and O'EF could be calculated, but the calculation would be rather difficult and therefore a solution which is partly graphical is more convenient and usually sufficiently accurate.

Let EO' and EO Fig. 11, be the center lines of two shafts which lie in the same plane and make an angle of 45 degrees with each other. The shafts are to be connected by two rolling cones so that the shaft O'E shall make 30 revolutions while the shaft OE makes 40. The base of the larger cone is 12 inches, to find the base of the smaller cone and the altitude of both. Since, from the preceding discussion, the speeds are inversely as the diameters of the cones, the larger cone must be on the shaft which is making the fewer number of revolutions, that is, O'E.

Then from formula (4).

$$\frac{\text{Speed of O'E}}{\text{Speed of O E}} = \frac{\text{Diameter of base of cone on O E}}{\text{Diameter of base of cone on O'E}}$$

$$\tfrac{3}{4} = \frac{\text{Diameter of base of cone on OE}}{12}$$

Solving the equation we get

Diameter of base of cone OE = 9 inches.

Now draw the line PN parallel to O'E and at a distance from O'E equal to the radius of the base of the cone O'E (in this case 6 inches), at a convenient scale, and draw the line ML parallel to OE and at a distance equal to the radius of the base of the cone on OE (in this case $4\frac{1}{2}$ inches). These lines intersect at the point C. A line from C to E is the element along which the cones touch each other. From C draw lines perpendicular to OE and O'E, meeting them at S and R respectively. Then SE and RE are the altitudes. To draw the cones, lay off ST equal to CS, and RV equal to CR. Join E with T and V and the cones are complete.

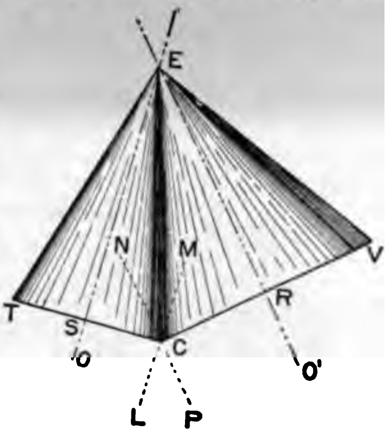


Fig. 11.

CYLINDERS AND CONES CONNECTED BY BELTS.

Frequently two shafts must be connected so that one may drive the other, and yet they are so far apart that cylinders cannot be placed on them which will touch each other. In this case it is customary to place on each shaft a cylinder, or pulley, and over these pulleys stretch a band, or belt made of some flexible material. The pulleys are fastened to the shafts so that the pulley and its shaft turn together, and the belt is stretched over the pulleys tight enough so that the friction between the belt and the surface of the pulley is sufficient to make them travel with the same linear velocity. A detailed study of the exact manner of finding the proper locations of the pulleys and drawing the pulleys and belts can be found in Mechanical Drawing Part V, so that we will

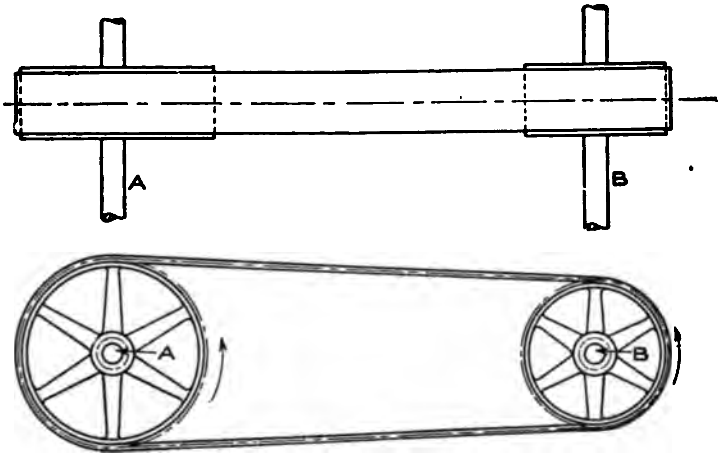


Fig 12.

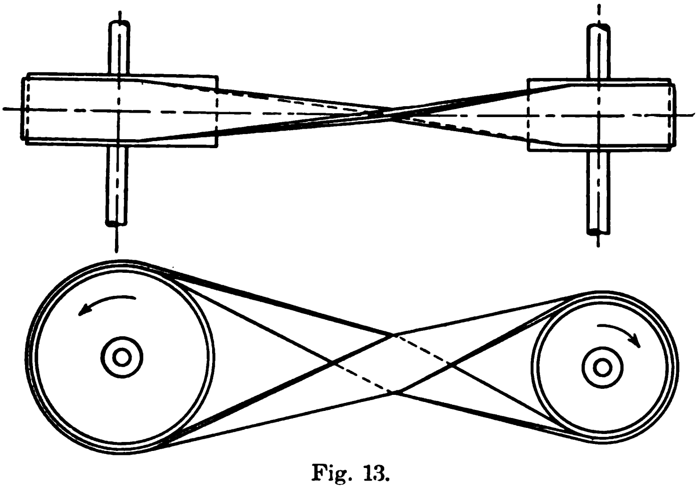


Fig. 13.

now st y only the general principles involved, particularly with referen to making the necessary calculations.

T principles which we learned above, concerning the relative speeds of two cylinders in contact, apply also to two pulleys connec by a belt. The rule governing the direction of rotation, howeve is different. When the connection is made by means of a belt, the relation of the directions of rotation depends upon the way the belt is put around the pulleys. If the belt is put on as shown in Fig. 12, known as open belt, the pulleys will turn in the same direction. If the belt is as shown in Fig. 13, known as a crossed belt, the pulleys will turn in opposite directions.

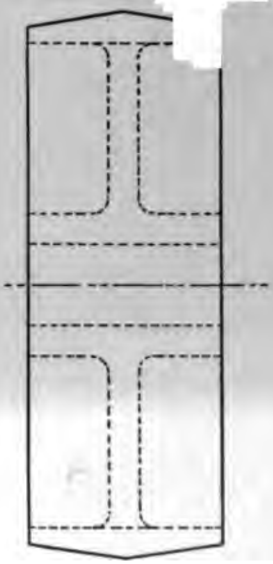


Fig. 14.

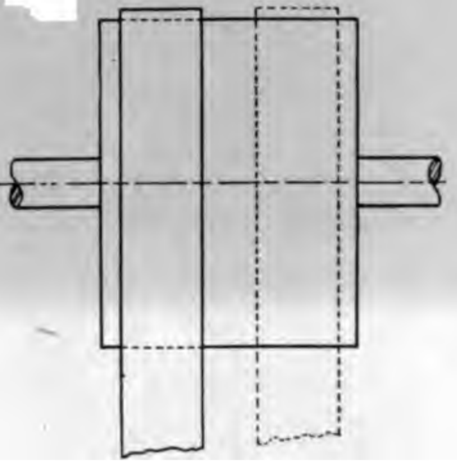


Fig. 15.

Crowning Pulleys. The outer surface of pulleys, instead of being made cylindrical is often made of larger diameter in the middle, as shown in Fig. 14. A pulley having this increase of diameter in the middle is said to have a crowned face. The object of the crowning is to help the belt to remain on the pulley. A belt will always run to the part of the pulley which is largest in diameter; therefore, if the diameter increases towards the middle, the belt will tend to run to the middle, and will be less likely to slip off. If the belt is to be at different places on the pulley at different times, as indicated by the full and dotted positions in Fig. 15, the surface cannot be crowned, but must be cylindrical.

As problems similar to the following often arise, this one should be studied carefully until every step is understood. In Fig. 16, A is a shaft turning 60 R. P. M. in the direction indicated by the arrow. B and C are cylinders over which a strand of cloth is to pass as indicated, the cloth passing over the top of B and under the bottom of C. In order that B and C may revolve in proper direction a crossed belt must be used between A and C, as shown. B is 24 inches in diameter, C is 18 inches in diameter, and the cloth is to travel at the rate of 120 feet per minute. E is a pulley 15 inches in diameter, which drives the pulley D, on the same shaft as B. F is a pulley 18 inches in diameter, driving pulley, G, on the same shaft as C. The problem is to find the number of revolutions of B and C, and the diameters of D and G.

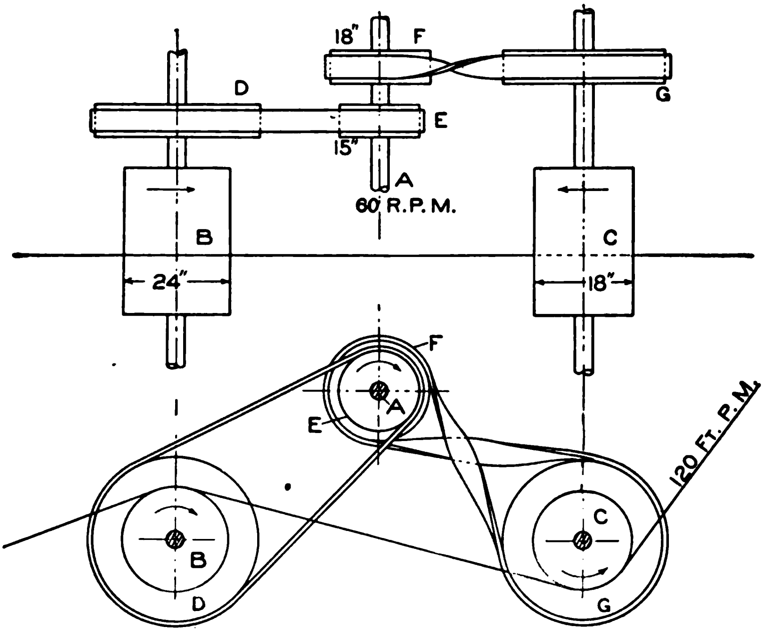


Fig. 16.

The circumference of B = 24 inches × π = 2 feet × π = 6.2832 feet. Therefore, its surface velocity if it made one R. P. M. would be 6.2832 feet per minute. But since it is to have a surface velocity = 120 feet per minute (equal to that of the cloth) its speed must be 120 divided by 6.2832 = 19.1 R. P. M. Revolutions of C are found in the same way.

18 inches = 1.5 feet. 1.5 feet × 3.1416 = 4.7124 feet = surface speed.

120 divided by 4.7124 = 25.4 R. P. M.

Now from formula (3):

$$\frac{\text{Revs. of D}}{\text{Revs. of E}} = \frac{\text{Diameter of E}}{\text{Diameter of D}}$$

and since the revolutions of D = the revolutions of B

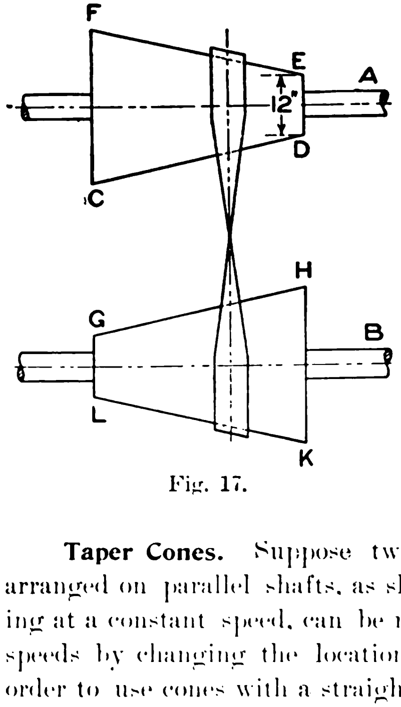


Fig. 17.

$$\frac{19.1}{60} = \frac{15}{x}$$

$$19.1\,x = 15 \times 60$$

$$x = 47.12 +$$

therefore, pulley D is 47⅛ inches in diameter.

$$\frac{\text{Revs. of G}}{\text{Revs. of F}} = \frac{\text{Diameter of F}}{\text{Diameter of G}}$$

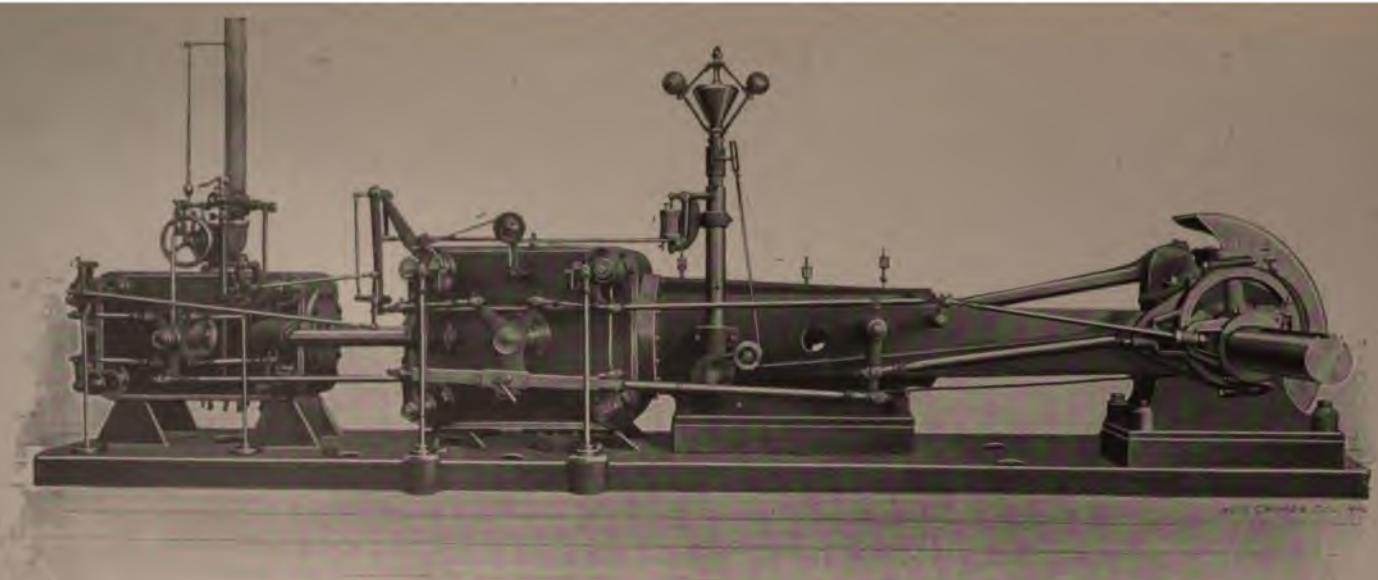
$$\frac{25.4}{60} = \frac{18}{x}$$

$$25.4\,x = 18 \times 60$$

$$x = 42.5 \text{ (approx.)}$$

therefore, pulley G is 42.5 inches in diameter.

Taper Cones. Suppose two equal frustums of cones are arranged on parallel shafts, as shown in Fig. 17. Shaft A, turning at a constant speed, can be made to drive shaft B at different speeds by changing the location of the belt on the cones. In order to use cones with a straight taper, a crossed belt should be used. If an open belt is used, the cones should be shaped as shown in Fig. 18. It is necessary to give this curvature to the face in order to keep the same tension on the belt for different positions. With a crossed belt this condition is fulfilled by making the face a straight line. If the shafts are far apart, the straight cones are sometimes used for an open belt.



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ASTOR, LENOX AND
TILDEN FOUNDATION

Since the calculations for finding the proper shape of the cones for an open belt are difficult and are not often needed, we will give our attention only to the straight cones for a crossed belt.

In Fig. 17 let shaft A be the driver, turning at a constant speed of 100 R. P. M. The small end of the cone on A is 12 inches in diameter. We wish to find the diameter of the large end of the cone on B, in order that the slowest speed of B may be 75 R. P. M. Then, if the cones are alike, to find the greatest speed of B:

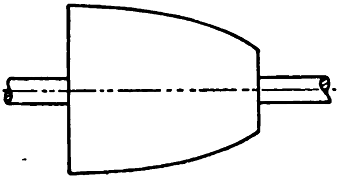


Fig. 18.

First $$\frac{\text{R. P. M. of A}}{\text{R. P. M. of B}} = \frac{\text{H K}}{\text{E D}}$$

$$\frac{100}{75} = \frac{\text{H K}}{12}$$

$$75\ \text{H K} = 12 \times 100$$

Therefore $$\text{H K} = \frac{1200}{75} = 16 \text{ inches.}$$

Now, if the cones are equal

and $$\text{G L} = \text{E D} = 12$$
$$\text{F C} = \text{H K} = 16.$$

Then $$\frac{\text{R. P. M. of A}}{\text{R. P. M. of B}} = \frac{\text{G L}}{\text{F C}}$$

$$\frac{100}{x} = \frac{12}{16}$$

$$x = \frac{1600}{12} = 133\tfrac{1}{3}.$$

Therefore, the larger ends of the cones must be 16 inches in diameter and B will have a variation of speed from 75 R. P. M. to 133⅓ R. P. M. The length of the cone does not affect the extreme speeds, but the longer the cones the more easily the intermediate speeds may be obtained.

Cones arranged as explained above are used to drive drying machines in bleacheries and similar places, where it is desired to vary the speed af the machine according to the weight of the cloth which is being dried. Heavy cloth requires a longer time to dry than light cloth and consequently can not be passed through the machine as rapidly. Tapered cones are also found in various cotton machines.

Stepped Cones. Stepped cones are often used in place of the tapered cones. These are really a series of pulleys side by side on a shaft, a similar series being placed on the other shaft with the large pulley on the second shaft in line with the small pulley on the first shaft. The arrangement is shown in Fig. 19. In practice the several pulleys which make up the stepped cones are cast together, both cones usually being cast from one pattern. The calculation for the diameters of the end steps are the same as for the end diameters for the cones (Fig. 17). Assuming that both cones are alike, the intermediate steps can be found as follows:—

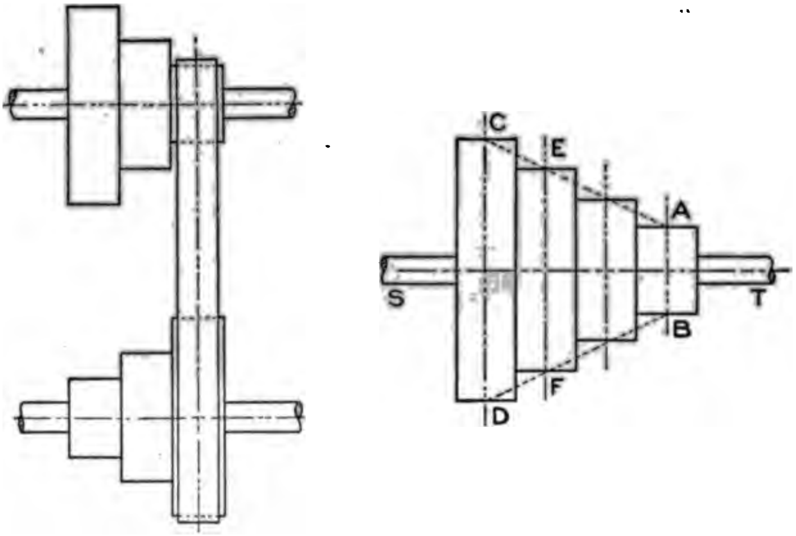


Fig. 19.

Decide how many intermediate steps are desired, then draw the center line ST, and draw the lines AB and CD perpendicular to ST and at a distance apart equal to the width of face of one step multiplied by the whole number of steps minus one. Make CD equal in length to the diameter of the largest step and AB equal to the diameter of the smallest step. Draw AC and BD. Draw EF parallel to and at a distance from CD equal to the width of the face of one step. The distance between E and F, the points where EF intersects AC and BD, will be the diameter of the second step. Other steps may be found in the same manner. To use this method all steps must have the same width of face. It would not be accurate for an open belt, although if the distance between the shafts are large compared with the diameter of the cones, an open belt might not give trouble on cones designed in this way.

Stepped cones are very commonly used for driving lathes and other machine tools.

EXAMPLES FOR PRACTICE.

1. A shaft making 115 revolutions per minute has keyed to it a pulley 36 inches in diameter. If the pulley belted to the 36-inch pulley is 26 inches in diameter, how many revolutions will it make per minute?

Ans. 160 revolutions. (nearly.)

2. A pulley 12 inches in diameter makes 180 revolutions per minute. The other pulley connected by belt to the 12-inch pulley should make 75 revolutions. How large must it be?

Ans. 28.8 inches in diameter.

3. A motor shaft having a pulley 6 inches in diameter makes 840 revolutions. If this speed is to be reduced to 320 revolutions, what size pulley should be used?

Ans. $15\frac{3}{4}$ inches in diameter.

Disk and Roller. Fig. 20 shows a device by means of which one shaft turning always in the same direction with a constant speed may drive another shaft, which is at right angles to it, in either direction and at different speeds. A is a disk on the end of the overhanging shaft S. On the shaft T is placed a roller B free to be moved up or down on T, but on a key so that it must turn with the shaft. Some sort of a shipper must be provided to hold B in the desired position on T. When one shaft turns it drives the other by means of the friction between A and B. If shaft S is the driver, turning in the direction indicated by the arrow, it will cause T to turn in the direction indicated by the lower arrow. If it is desired to have T turn in the opposite direction, keeping the direction of S the same, B must be moved up above the center line of S as shown dotted. If OR is the distance from the center of disk A to the point where the center line of the face of B strikes

A, and LR is the radius of B, we have the following equation,—

$$\frac{\text{R. P. M. of B}}{\text{R. P. M. of A}} = \frac{\text{O R}}{\text{L R}} \qquad (6)$$

from which, knowing the speed of one, the speed of the other may be calculated. It will be seen from this equation that if OR is decreased, that is, if B is moved nearer the center line of S, the speed of B will decrease if A is the driver, or the speed of A will increase if B is the driver.

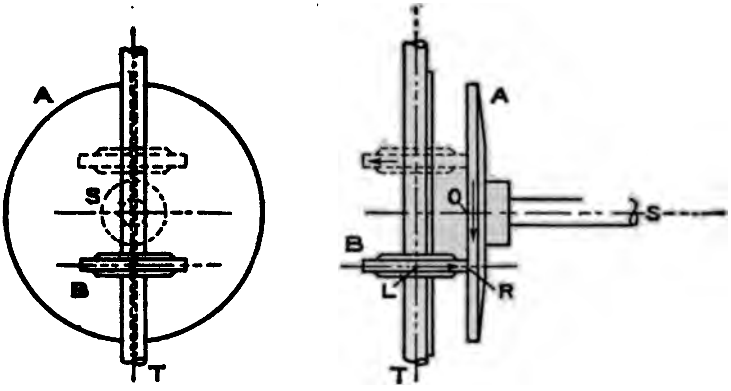


Fig. 20.

This device is used for driving drying machines where the cloth goes from another machine direct to the drying machine, and it is essential that the speed of the two should be adjusted to a nicety, in order that excessive strain may not come upon the cloth. It is also used for driving the feed mechanism on machine tools, particularly drills.

Example: Suppose the disk A makes 70 revolutions per minute and disk B 124 revolutions. If OR is 18 inches what is the diameter of B?

$$\frac{\text{R. P. M. of B}}{\text{R. P. M. of A}} = \frac{\text{O R}}{\text{O L}} \text{ or } \frac{124}{70} = \frac{18}{\text{OL}}$$

$$124 \times \text{O L} = 70 \times 18$$

$$\text{O L} = \frac{70 \times 18}{124}$$

$$= 10.16 \text{ inches (about).}$$

Diameter would be 2 × 10.16 = 20.32 inches or 20$\frac{5}{16}$ inches.

EXAMPLE FOR PRACTICE.

1. Disc B, Fig. 20, is 12 inches in diameter and makes 280 revolutions per minute. If shaft S is to make 48 revolutions per minute how far from the center must the circumference of B be placed? Ans. 35 inches.

DISCONNECTING AND REVERSING MECHANISMS.

Tight and Loose Pulleys. Fig. 21 shows a very common arrangement of pulleys, whereby the shaft A may be stopped while the driving shaft B continues to run. Pulley C is keyed to shaft A, while pulley D is free to run on A. Pulley E has its face equal in width to the sum of the other two and is keyed to B. When the belt is in the position shown in full lines, D turns with E, while shaft A remains at rest. The belt is guided by a shipper and when it is desired to start A, the belt is moved into the position shown by the dotted lines.

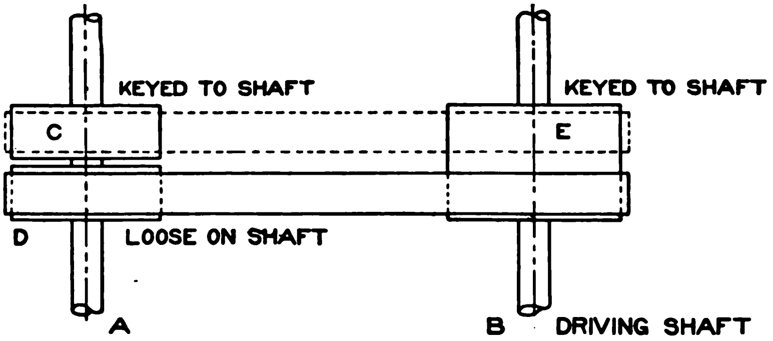


Fig. 21.

Jaw Clutch. Fig. 22 illustrates an arrangement by which the gear, or pulley, A may be attached to turn with the shaft, or disconnected so as to turn independently of the shaft. The hub of A has jaws or teeth on its end, and the sliding piece B has similar teeth, the projections on B fitting into the indentations of A. The shaft may turn freely in A while B slides on a key so that it must turn with the shaft. When B is in the position shown, the shaft and A may turn independently of each other, but when B is noved to the left so that its teeth engage with the teeth on the b of A, it serves to clamp A to the shaft. The principle here involved is used in many different forms of clutches.

Friction Clutches. A jaw clutch such as illustrated in Fig. 22, if thrown in while the shaft or gear is turning brings a sudden shock on the parts, which is likely to cause damage, especially if the speed is high and much power is transmitted. Consequently, a clutch known as a friction clutch is often used, which, as its action depends upon the friction between two parts, will impart motion more gradually thereby avoiding the shock. Fig. 23 illustrates a simple clutch of this kind. B is a piece free to slide on a key, and held in position by a shipper. A is a pulley or gear loose on the shaft. The outer surface of B and the inner surface of A are tapered to fit each other. When B is thrown to the left it clamps A to the shaft in the same manner as the jaw clutch.

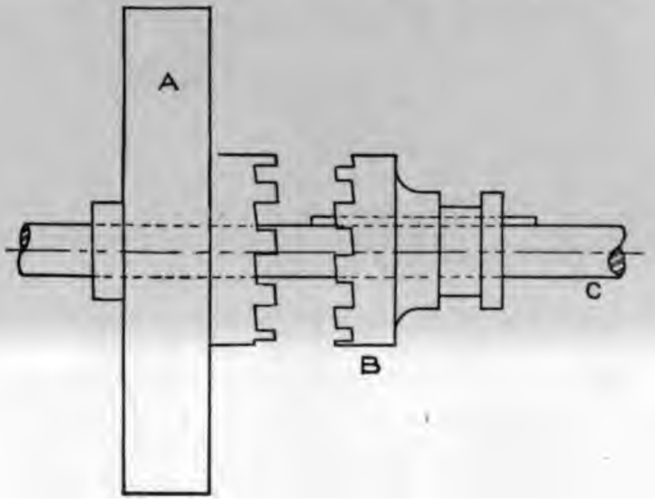


Fig. 22.

Two Clutches for Reversing. Fig. 24 shows how two clutches can be arranged so that either one may be thrown in, thus giving motion to the shaft in either direction. The clutches are similar in principle to the one shown in Fig. 23. The left-hand clutch is shown partly cross-sectioned. The piece A is attached to a shipper which when moved to the right throws in the right-hand clutch; when moved to the left throws in the left-hand clutch. If the pulley of the right-hand clutch is driven by an open belt and the pulley of the left-hand clutch by a crossed belt, the shaft will be driven in either direction according as one or the other clutch is thrown in. When A is in the position shown neither clutch is in and the shaft is at rest.

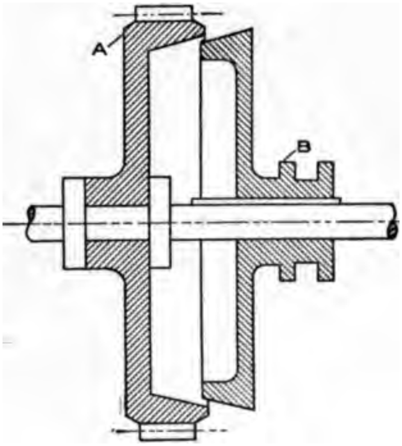


Fig. 23.

SCREWS.

The Helix. Since all screws depend upon a curve known as the helix, it will be necessary to understand something about this curve before attempting the study of the screw.

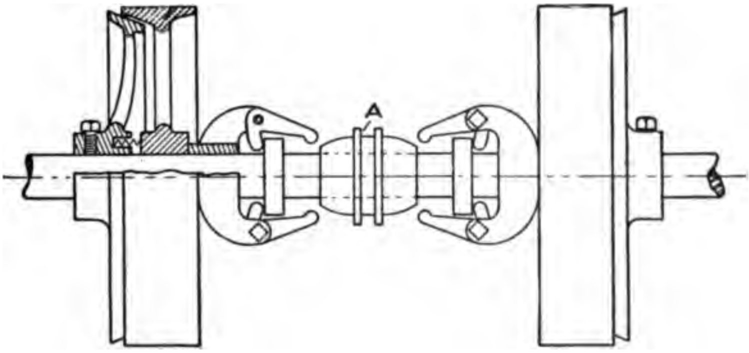


Fig. 24.

Take a cylindrical piece of wood, such as is shown in Fig. 25, and a rectangular piece of paper, ABFE, with the side AB equal

nference of the cylinder, and the side AE equal to the
e cylinder. Now, if we lay off along AE a distance

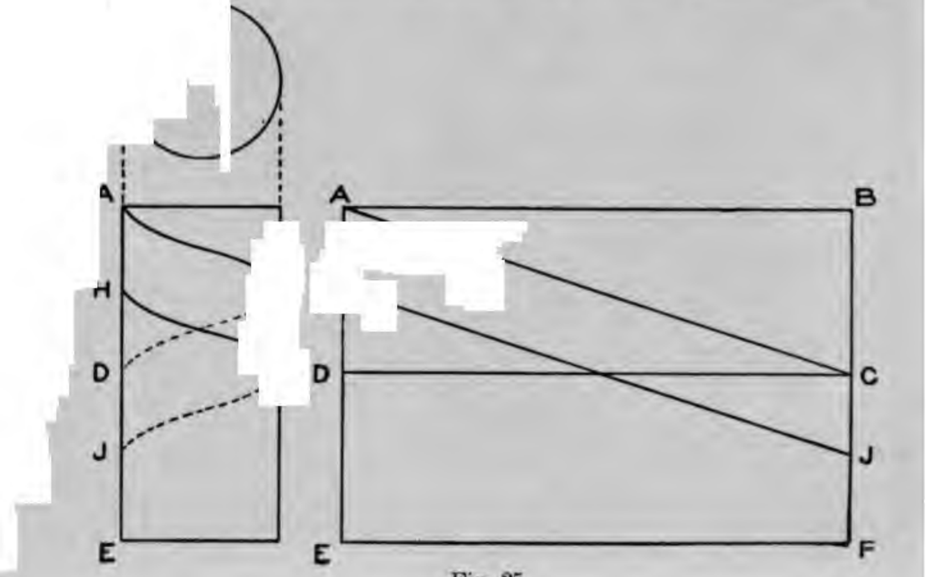


Fig. 25.

AD, and draw the line DC parallel to AB, we have the rectangle, ABCD. Now draw the diagonal, AC, of the rectangle and wrap the paper around the cylinder, keeping the side AE on an element of the cylinder; the paper will just cover the cylinder, the edge

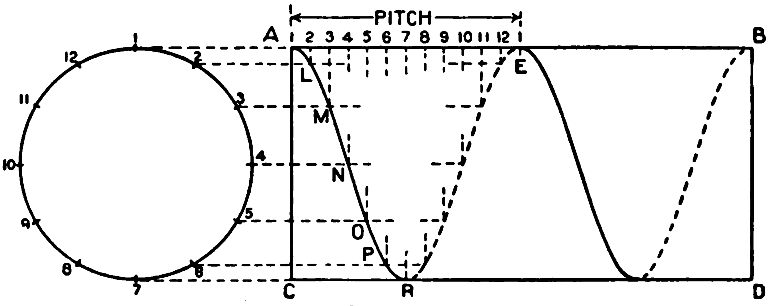


Fig. 26.

BF meeting the edge AE. The point C will coincide with D and lie on the same element of the cylinder as A and at a distance from A equal to AD. The shape which the line AC now takes is called a helix, and the distance AD is called the pitch of the helix. If we choose another point, H, half-way between A and D, and draw a line HJ parallel to AC, this line when wrapped around the cylinder will form another helix of the same pitch as the first one. The two together form what may be called a double helix. If the line AD is divided into three equal parts instead of two, and lines parallel to AC be drawn from each of the points of division, we would have on the cylinder three parallel and equidistant helices of the same pitch, or a triple helix. Fig. 26 shows a single right-hand helix, Fig. 27 a single left-hand helix, Fig. 28 a double right-hand helix, and Fig. 29 a triple right-hand helix.

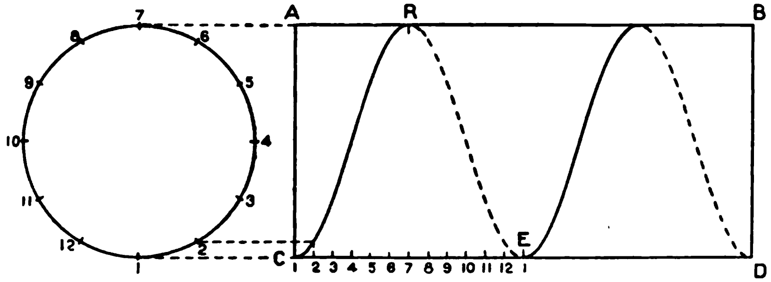


Fig. 27.

If a helical groove is cut on the surface of a cylinder, a screw thread is formed, the thread being the material which is left between the successive turns of the helical groove. A cylinder having a thread on it is called a screw, and a piece having a cylindrical hole in it, with a thread around the hole, is called a nut. The groove which is cut to form the thread may be in the form of a single, double or triple helix, and either right-hand or left-hand; the thread would be described in the same terms.

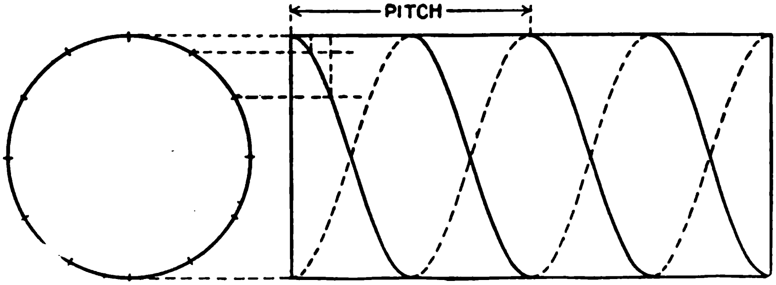


Fig. 28.

Fig. 30 shows a right-hand and a left-hand single V thread and a right-hand and a left-hand single square thread.

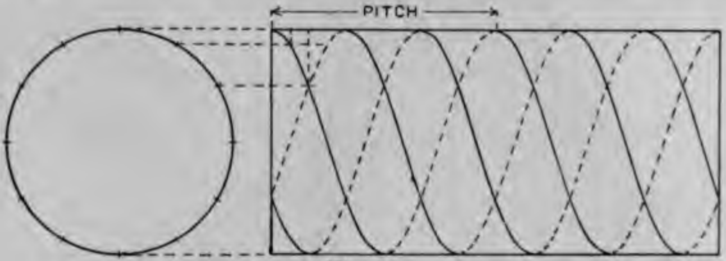
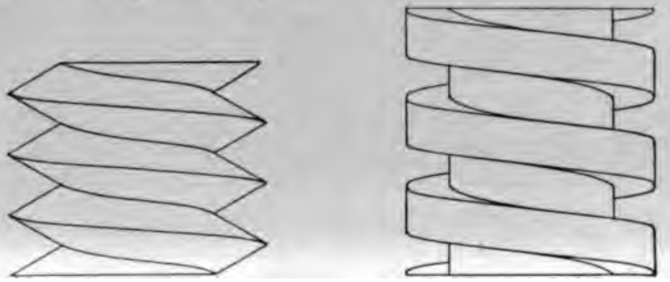
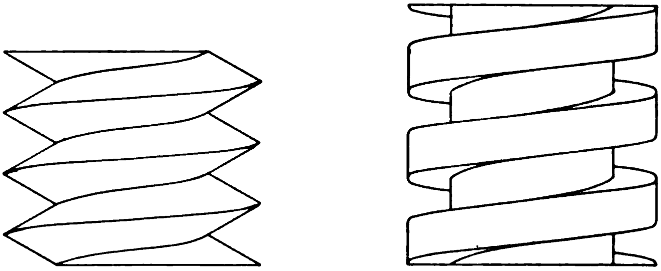


Fig. 29.

One complete turn of a screw causes it to travel through its nut a distance equal to its pitch.



LEFT-HAND THREAD. **LEFT-HAND THREAD.**



RIGHT-HAND THREAD. **RIGHT-HAND THREAD.**

Fig. 30.

There are certain principles which apply and certain problems which arise, in connection with all forms of screws, and we shall now consider some of the most important of these.

Let Fig. 31 represent a jack screw. The pitch of the screw is P inches; the length of the bar from the axis of the screw to the point R, where the force is applied, is A inches. A force of F pounds is exerted at R, raising the weight W.

The following equation holds true,

$$\frac{F}{W} = \frac{\text{Distance W moves}}{\text{Distance F moves}} \qquad (7)$$

Suppose the screw to be turned once; then F will move through a distance approximately equal to the circumference of a circle whose radius is A; that is, F moves a distance $2\pi A$. In turning the screw once, W is raised a distance P. Then, substituting, in equation (7), these quantities for the distances which F and W respectively move, we get

$$(8)\ \frac{F}{W} = \frac{P}{2\pi A} \quad \text{or}$$

$$2\pi A F = W \times P$$

$$W \times P = 2\pi A \times F$$

From this equation, if any three of the quantities F, W, P or A are known, the fourth may be found. P and A must both be expressed in feet or both in inches.

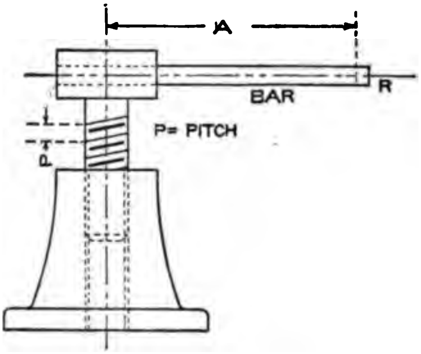


Fig. 31.

For example, let P = $\frac{1}{4}$ inch, A = 5 feet, F = 100 pounds. Substituting in the formule we get

$$\frac{100}{W} = \frac{.25}{2 \times 3.1416 \times 60}$$

$$.25\ W = 37699.2$$

$$W = 150{,}797 \text{ pounds (nearly).}$$

EXAMPLES FOR PRACTICE.

1. Suppose a weight of 200,000 pounds is to be raised by a jack screw. The pitch is .20 inch, and the force applied is 125 pounds. What must be the length of the bar?

Ans. 51 inches (nearly).

2. What should be the pitch of the screw of example 1 if the bar is made 6 feet long? Ans. .28+ inches.

3. A jack screw has the following dimensions: Length of arm, $5\frac{1}{2}$ feet; pitch, .125 inch. If 200,000 pounds are to be raised what force must be applied at the end of the bar?

Ans. 60 pounds.

Combination of Screws. Fig. 32 illustrates a method by which the space moved through by the nut C may be made very small in comparison with the space moved through by a point on the circumference of the hand wheel, without using a very fine pitch on the screw. Great pressure can thus be produced at C by a small force on the wheel, without danger of stripping the thread, which might occur if the screw had a fine pitch. The upper part of the screw E has a coarse thread which acts in the nut B, this nut being rigid with the frame D. The lower part of the screw has a pitch different from the upper part and acts in the nut C. C is free to slide up or down in the frame, but is prevented from turning by the lips L.

Let P = the pitch of the upper part of the screw and p = the pitch of the lower part, both threads being right-hand, and P being greater than p. If the screw were attached to C by a collar instead of being threaded into it, one turn of the screw right-handed in nut B would cause the screw to advance a distance P, carrying C forward the same distance. But since by the same turn the screw has drawn nut C on to itself a distance p, the actual distance, K, which C has advanced is

$$K = P - p \qquad (9)$$

If p were greater than P, K would have a minus value; that is, C would actually move up for a right-handed turn of the screw. If one of the screws is left-handed and the other right-handed, the equation would become

$$K = P + p. \qquad (10)$$

Let $P = \frac{1}{4}$ inch and $p = \frac{3}{16}$ inch, and let both screws be right-handed. If the radius A of the hand wheel is 12 inches, how much pressure can be exerted at C by a force of 50 pounds, applied to the circumference of the wheel?

The same principle holds here as in the case of a simple screw; that is, the forces exerted are inversely as the distances moved through, or,

$$\frac{\text{Force at wheel}}{\text{Force at C}} = \frac{\text{Travel of C}}{\text{Travel of point on circum. of wheel}} \qquad (11)$$

so that we must first find the distance C moves for one turn of the wheel. Substituting the values of P and p in formula (9), we get

$K = \frac{1}{4} - \frac{3}{16} = \frac{1}{16}$ = distance C moves for one turn of the screw.

The distance which a point on circumference of wheel moves

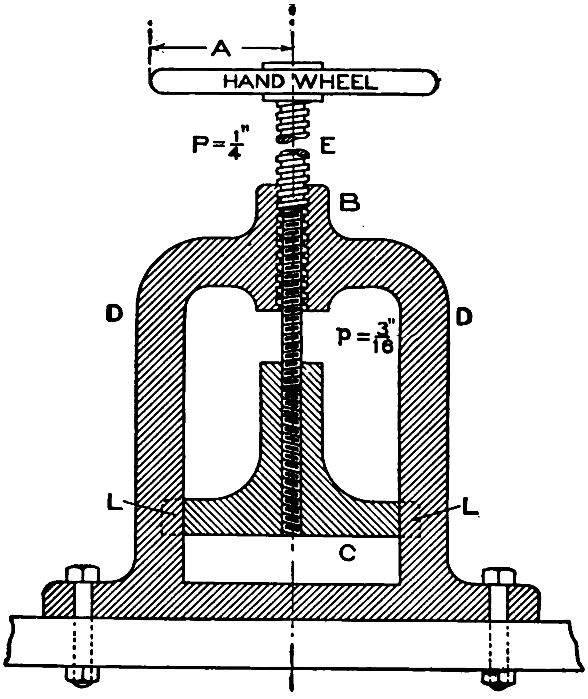


Fig. 32.

$= 2\pi A = 2 \times 3.1416 \times 12 = 75.4$ inches. Substituting these values in formula (11) we get

$$\frac{50}{\text{Force at C}} = \frac{\frac{1}{16}}{75.4}$$

Solving, we get, force at C = 60,320 pounds.

EXAMPLE FOR PRACTICE.

1. uppose the press shown in Fig. 32 has the following ensions: $P = \frac{1}{5}$ inch, $p = \frac{1}{6}$ inch, and the force at C is to be 78, 0 pounds. What force must be applied to the circumference of the wheel if it is 14 inches in diameter?

Ans. 60 pounds (nearly).

Worm and Wheel. The mechanism known as worm and wheel consists of a wheel, as A, Fig. 33, having teeth on its circumference, and a screw or worm W, meshing with the teeth on the wheel. The axis on wheel is fixed is usually at right angles to the axis of . If the worm is turned, the action between it and the te on the wheel is similar to the action between a screw and the d in a nut, so that the wheel will turn also. If the worm is single-threaded, one turn of the worm will cause the wheel to advance one tooth, so that in order for the wheel to make one complete revolution, as many turns of the worm will be required as there are teeth in the wheel. If the worm is double-threaded, half as many turns will be required as there are teeth in the wheel; if the worm is triple-threaded, one-third as many turns will be required as there are teeth in the wheel.

Suppose the worm be single-threaded and turned by a crank whose length is R; let the worm wheel have n teeth and have on its shaft a cylinder of radius K, with a cord wound around it supporting the weight L. If a force of F pounds is applied to the crank, the same principle holds true as in the other mechanisms which we have studied, namely,

$$\frac{F}{L} = \frac{\text{Distance L moves}}{\text{Distance F moves}} \qquad (12)$$

If the worm makes one revolution, F will move through a distance $2\pi R$. The wheel makes $\frac{1}{n}$ revolutions, and consequently the cylinder to which L is attached will make $\frac{1}{n}$ revolutions. If the cylinder made a whole revolution it would raise L a distance equal to its circumference $= 2\pi K$, therefore, when it makes one revolution it will raise L a distance $\frac{2\pi K}{n}$ Substituting this value for the distance L moves, in formula (12), and substituting for distance F moves, the quantity $2\pi R$, we get

$$\frac{F}{L}=\frac{\frac{2\,\pi\,K}{n}}{2\,\pi\,R}=\frac{2\,\pi\,K}{2\,\pi\,nR}$$

Therefore, $$\frac{F}{L}=\frac{K}{nR} \tag{13}$$

If the worm is double-threaded, L will be raised twice as far for one turn of the worm, so that the above formula would become for a double-threaded worm and wheel,

$$\frac{F}{L}=\frac{2\,K}{n\,R} \tag{14}$$

and for a triple-threaded worm and wheel,

$$\frac{F}{L}=\frac{3\,K}{n\,R} \tag{15}$$

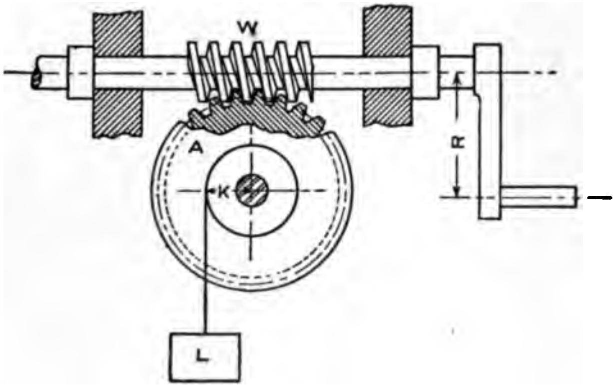


Fig. 33.

For example, a single-threaded worm makes 180 revolutions per minute and the worm wheel has 30 teeth, how many feet per minute will a weight be raised if the cylinder on the shaft of the worm wheel is 12 inches in diameter?

For each revolution of the worm wheel the worm must make 30 revolutions, hence the worm wheel makes 6 revolutions per minute. The circumference of the cylinder is $2\,\pi\,R$ or $2 \times 3.1416 \times 6 = 37.699$ inches and $6 \times 37.699 = 226.197$ inches $= 18.85$ feet.

EXAMPLES FOR PRACTICE.

1. A crank of 18 inches radius is attached to a worm of a single thread. The worm wheel has 48 teeth and is attached to a drum 14 inches in diameter. What weight can be raised if 80 pounds is applied to the crank?

Ans. 9874 pounds.

2. If the crank in above device is given 216 revolutions per minute how fast will the weight rise?

Ans. 16½ feet (nearly).

3. How fast would it rise if the worm has a double thread?

Answer 33 feet.

CAMS.

A cam is a plate or cylinder having a curved outline, or a curved groove in it, which, by its rotation about a fixed axis, imparts a backward and forward motion to a piece in contact with it. The motion imparted to the follower may be at right angles to or parallel with the axis of the cam, or at some other angle.

The motions which cams are designed to give to their followers commonly belonged to one of the following kinds: uniform motion, harmonic motion, or "gravity" motion. The cam may give one kind of motion all the time or it may give different kinds of motion at different stages in its revolution.

Before studying the cams themselves, we will consider the three kinds of motions mentioned.

Uniform Motion. If a body moves through equal spaces in equal intervals of time, it is said to have uniform motion, that is, its velocity is constant.

Harmonic Motion. If a point as C, Fig. 34, travels around the circumference of a circle with uniform velocity, and another point, as E, travels across the diameter at the same time at such a velocity that it is always at the point where a perpendicular let fall from C would meet the diameter, the point E would be said to have harmonic motion. Its velocity will increase from the starting point A until it reaches the center O, and from O to D its velocity gradually decereases to zero at D.

Gravity Motion, or uniformly accelerated and retarded motion, is also a motion where the velocity gradually increases until it reaches a maximum at the middle of the path and from there gradually decreases to the end. The rate of increase and decrease, however, is different from that in harmonic motion, the velocity being increased in gravity motion, by equal amounts in equal intervals of time, the spaces traveled over in successive intervals of time being in the ratio of 1, 3, 5, 7, etc., to the middle of the path, and decreasing in the same ratio to the end.

The kind of motion which the follower is desired to have must be taken into consideration when designing a cam.

Plate Cams. Fig. 35 shows a plate cam designed to raise and lower the follower P with uniform motion. The point of P is raised from A to *e* while the cam turns right-handed through two-thirds of a revolution, and is lowered again to its original position during the remaining one-third of a revolution of the cam. In this cam the line of motion to the point of P passes through the point O, which is the center of the shaft on which the cam is fixed.

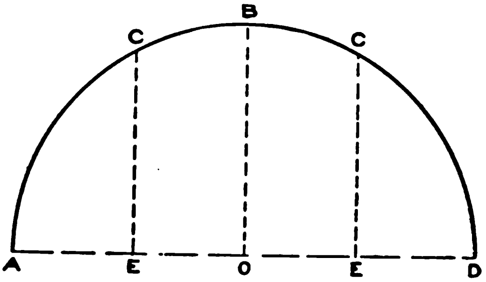


Fig. 34.

To design such a cam, draw a circle with O as a center and passing through A. Since the raising of P is to take place during two-thirds of a revolution, right-handed, find a point E on the circumference of the circle, such that the arc AHE shall be $\frac{2}{3}$ of the whole circumference, thus leaving arc ACE equal to $\frac{1}{3}$ of the circumference. Divide the arc AHE into any number of equal parts and draw the radial lines OF, OG, etc. Divide A*e* into the same number of equal parts and from the points of division 1, 2, 3, etc., thus found, swing arcs around the center O, cutting OF, OG, etc., at points *f*, *g*, etc., respectively. A smooth curve drawn through A, *f*, *g*, etc., to *m*, will give the outline of that part of the cam which raises P. The outline of the rest of the cam is found in a similar manner, by dividing arc ACE into any number of equal parts and making a new division of A*e* into the same number of equal parts, (points *d*, *c*, *b*.)

Fig. 36 shows a cam which gives the same motion to the follower as was given by the cam shown in Fig. 35, but in this case the line of motion of P, instead of passing through O, passes a distance O*a* to one side of O. The only difference in the method of designing this cam from that previously described is that instead of drawing radial lines through points A, F, G, etc., we draw lines through these points tangent to a circle drawn with center O and radius O*a*.

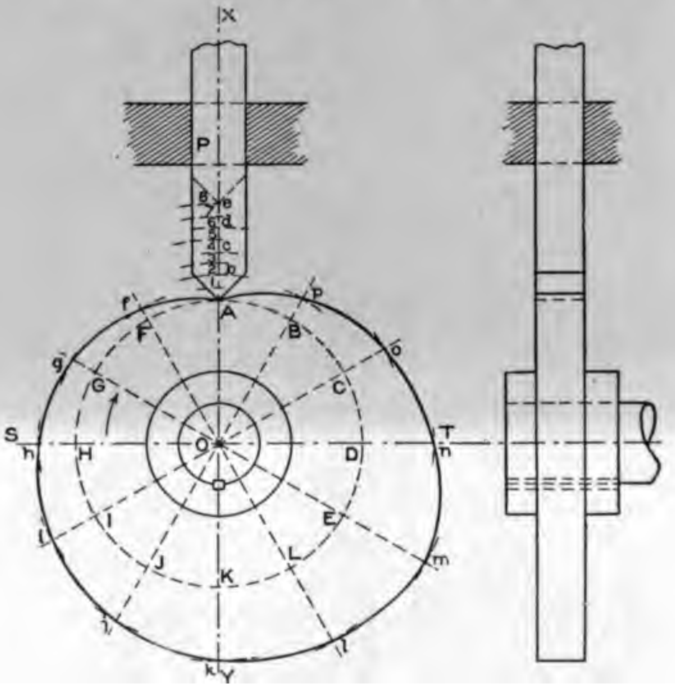


Fig. 35.

If in Figs. 35 and 36 it had been required to raise P with harmonic motion instead of uniform motion, the only difference in construction would have been in making the divisions of A*e*. These divisions, instead of being equal, would be found as shown on a larger scale in Fig. 37. On the line A*e* as a diameter, draw a semicircle and divide this semicircle into as many equal parts as we divided the arc AHE in Figs. 35 and 36. From the points

BCD, etc. (Fig. 37), draw perpendiculars to line A*e*, cutting it at points 1, 2, 3, etc. The division A – 1, 1 – 2, etc., thus found, are the divisions of A*e* which would be used in finding the cam outline, in place of the equal divisions which were used for uniform motion.

Fig. 38 shows how A*e* would be divided if the motion were to be "Gravity." Since A*e* is to be divided into as many equal parts as arc AHE, in this case it will be divided into eight parts. Now if the motion which the cam is to give to piece P is to be uniformly accelerated and retarded (that is, gravity motion), A*e* must be divided in such a way that the distance from 1 to 2 is three times the distance from A to 1; the distance from 2 to 3 is five times the distance from A to 1; 3 to 4 is seven times A to

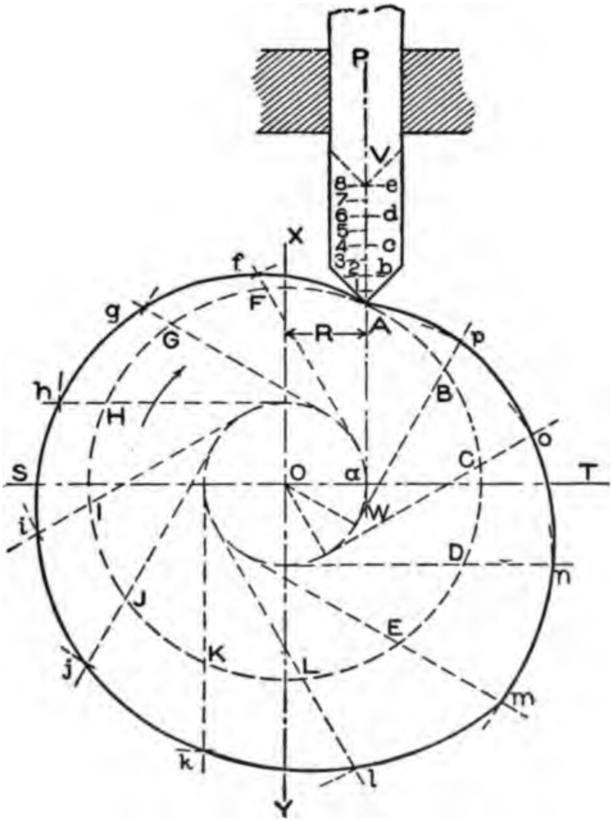


Fig. 36.

1; 4 to 5 is seven times A to 1; 5 to 6 is five times A to 1; 6 to 7 is three times A to 1; and 7 to *e* is equal to A to 1. Therefore the whole line A*e* is 1+3+5+7+7+5+3+1 or 32 times the distance from A to 1, or in other words, A–1 is $\frac{1}{32}$ of the whole line A*e*, and 1–2 is $\frac{3}{32}$ of A*e*, and so on. To divide A*e* so that the divisions may bear this relation to each other, draw the line AR at any convenient angle, and choosing any convenient distance as a unit, mark it off on AR thirty-two times, beginning at A. From I, the last of these dividing points, draw a line to *e*; next find the points B, C, D, etc., as follows: B is the first division from A, C the third from B, etc., thus getting the divisions of A1 in the ratio 1, 3, 5, 7, 7, 5, 3, 1. From the points B, C, D, etc., draw lines parallel to 1*e*, meeting A*e* at 1, 2, 3, etc., which will be the required points of division.

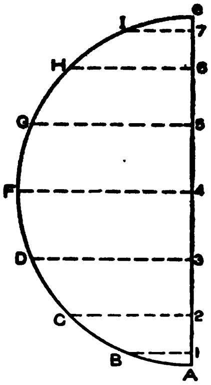


Fig. 37.

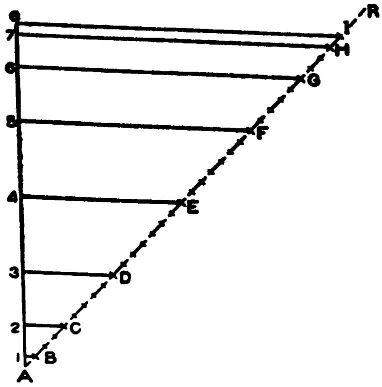


Fig. 38.

The cams which we have been considering all act on the comparatively sharp end of the piece P, and consequently much friction and rapid wearing will result if much power is transmitted. Fig. 39 shows a cam designed to act on a roller. The outline is first found for a cam to act on a piece like those in the preceding cases, with its point at the center of the roller. This curve is shown dotted in the figure. Next, with a radius equal to the radius of the roller, and with centers at any number of points around the dotted curve, draw arcs as shown. A smooth curve drawn *tangent* to these arcs will be the outline of the cam which is to act on the roller.

Cylindrical Cams. A plate cam, such as we have been considering, can be designed to give almost any kind of motion in a plane at right angles to the axis of the shaft on which the cam is located, but can not give motion parallel to the axis of the shaft. If, however, we place on the shaft a cylinder with a groove cut in it, the shape of the groove may be made such as to give to a piece inserted in it almost any motion along the shaft; or, if the depth of the groove be varied, the follower may be given a motion which shall be made up of two components, one along the shaft and one at right angles to the shaft.

Fig. 40 shows two views of a cam designed to give a backward and forward motion in a line parallel to the axis of the shaft.

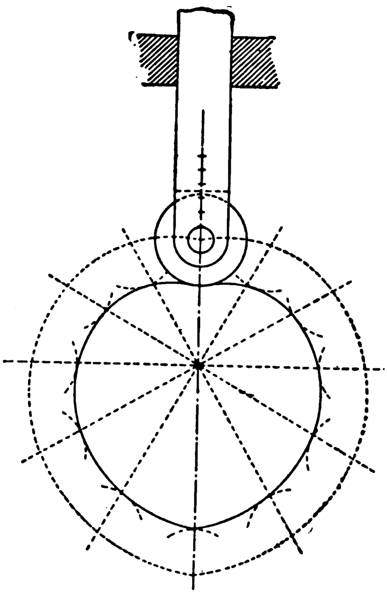


Fig. 39.

Familiar illustrations of the use of plate cams are found in the bobbin-winding mechanism on some sewing machines; on many kinds of looms, and in the valve gear on the Brown and other steam engines. Cylindrical cams are used in many places

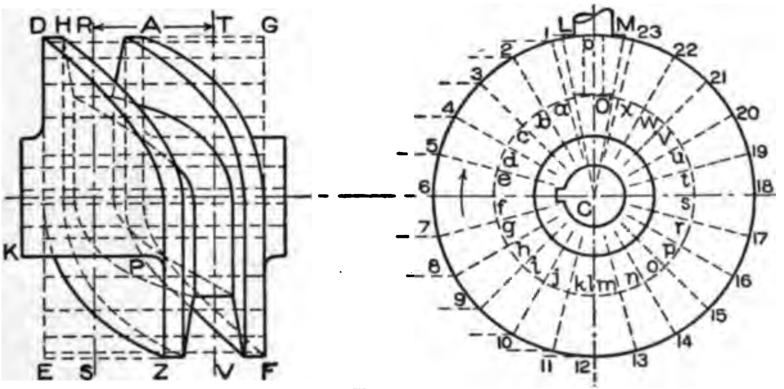


Fig. 40.

work and in machine tools. One very common use is in stretchers on many forms of cloth-finishing machinery.

LEVERS.

A lever is a rigid piece supported at some point called the fulcrum, and so arranged that when force is applied at a certain point in the piece, work is done at a certain other point by reason of the pivoting action around the fulcrum. Figs. 41, 42 and 43 illustrate the three common kinds of levers, the difference consisting in the relative positions of the force applied and the weight lifted, with respect to the fulcrum. In any of the three cases, if we let F = force applied, W = weight lifted, A = distance from fulcrum to weight, and B = distance from fulcrum to F, we have the following equation:

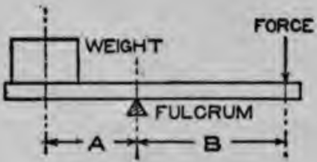


Fig. 41.

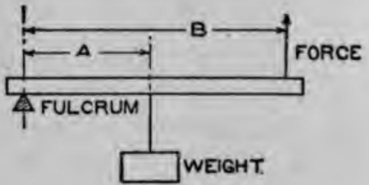


Fig. 42.

$$F \times B = A \times W \text{ or}$$

$$\frac{F}{W} = \frac{A}{B} \qquad (16)$$

from which, if any three of the quantities are known, the fourth may be found.

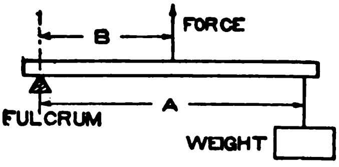


Fig. 43.

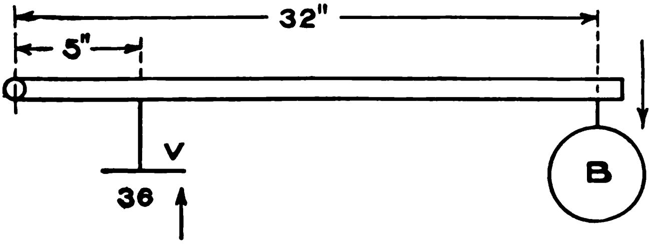
Distance A is called the *weight arm*, and distance B is called the *power arm*. The product of A times the weight is called the moment of the weight, and the product of B times the force is called the moment of the force. Another way of stating the principle expressed in equation (16) is:

Moment of force = moment of weight.

Example: Suppose a weight of 40 pounds is hung on the end of a lever. If the distance from the fulcrum to the weight is 14 inches, what power must be applied to raise the weight, the distance from the fulcrum to the power being 18 inches?

$$F \times B = A \times W$$
$$F \times 18 = 14 \times 40$$
$$F = \frac{14 \times 40}{18}$$
$$= 31.11 \text{ pounds.}$$

Another example: Let the accompanying diagram represent a safety valve. We will neglect the weight of the lever and valve. Suppose the valve V has an area of 3 square inches and the steam pressure per square inch is 36 pounds. The valve is 5 inches from the fulcrum and the weightis 32 inches from the fulcrum. What should be the weight of the ball B?



First, let us find the moment of power. The total upward pressure is 3 × 36 = 108, because the total steam pressure equals the pressure per square inch multiplied by the area.

The moment of power is 108 × 5 = 540.

The moment of weight is 32 × B.

$$\text{Then } 32 \times B = 540$$
$$B = \frac{540}{32}$$
$$= 17 \text{ pounds (nearly).}$$

Had we considered the weight of the valve and lever, we would have added their moments to that of the weight, because these weights increase the weight but not the power.

If in addition to the data given above, the lever weighs 10 and its center of gravity is at its center, that is, 16 inches from the fulcrum. Then

$$\text{Moment of lever} = 10 \times 16 = 160.$$

The valve and valve spindle weigh 8 pounds and are 5 inches from the fulcrum, hence

$$\text{Moment of valve} = 8 \times 5 = 40.$$

$$\text{Total moment of weight} = 32 \times \text{B} + 200.$$

The moment of power is, from the previous example, 540, and we have the equation

$$\begin{aligned} 32 \times \text{B} + 200 &= 540 \\ 32\,\text{B} &= 540 - 200. \\ 32\,\text{B} &= 340 \\ \text{B} &= \frac{340}{32} = 10.62 + \text{pounds.} \end{aligned}$$

Thus we see that by considering the weight of the valve and spindle and that of the lever, the ball can be reduced in weight from 17 to 10$\frac{5}{8}$ pounds.

If the lever is curved as in Fig. 44, the weight arm A becomes the length of the perpendicular from the fulcrum to the line of action of the weight, and the power arm B the length of the perpendicular from the fulcrum to the line of action of the force.

LINK WORK.

Four-Bar Linkage. If we have the four rods AB, BC, CD and DA, Fig. 45, each connected to two of the others by pin and eye joints, each rod becomes what is called a link, and the whole forms a four-bar linkage. If the link AB is fixed in a position (as regards the frame of the machine) the pins at A and B become fixed centers, the links AD and BC become what are called cranks, and the link CD becomes a connecting link or connecting rod. If AD is caused to turn with a uniform angular speed about the pin of A, that is, turning through equal angles in equal periods of time, BC will be compelled to turn with some sort of motion about pin B. Whether BC shall have uniform angular motion and whether it shall make complete revolutions for complete revolutions of AD, will depend upon the relative lengths of the four links.

The center line drawn through the fixed link AB is called the line of centers, and the center line drawn through the connecting rod CD is called the line of connection. Whatever the relative lengths of the various links, the following law holds true for any position of the linkage.

$$\frac{\text{Angular velocity of crank A D}}{\text{Angular velocity of crank B C}} = \frac{\text{B H}}{\text{A K}} = \frac{\text{B E}}{\text{A E}} \qquad (17)$$

That is, if at any given instant the connecting rod be imagined removed and the cranks continue turning at the same speed at which they were moving when the connecting rod was removed, the number of turns of the cranks in a given period of time would be to each other inversely as the lengths of the perpendiculars drawn from the respective fixed centers to the line of connection, and also inversely as the distances from the fixed centers to the point where the line of connection meets the line of centers. A mathematical proof can be given for this law, but it will not be considered here.

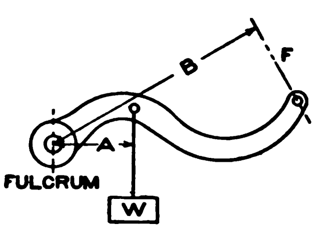


Fig. 44.

If the fixed link AB is made equal in length to the connecting rod DC, and the two cranks are equal (see Fig. 46), the connecting rod will always be parallel to the fixed link, and the perpendiculars BH and AK will always be equal, so that from equation (17) it will be evident that the speeds of the cranks are always equal. An example of a linkage of this kind is found in the parallel rod connecting the drivers of a locomotive, as shown in Fig. 47. The axles of the drivers form the fixed centers A and B, the

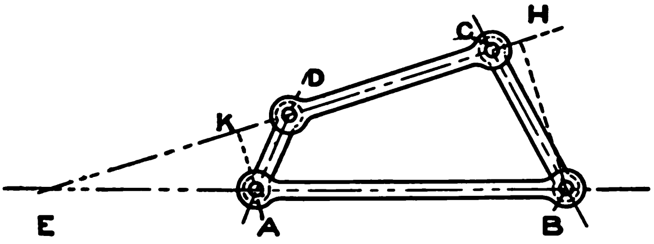


Fig. 45.

frame of the locomotive forms the fixed link AB, the drivers themselves form the cranks AD and BC, and the parallel rod forms the connecting link.

Crank and Connecting Rod. In the four-bar linkage shown in Fig. 45, the pin C is compelled by crank BC to move on the arc of a circle whose center is B and radius BC. If in place of BC the fixed link is formed as shown in Fig. 48, being provided with a slot whose radius is BC and center is B, the pin C on the end of the connecting rod will have exactly the same motion that it would if guided by the crank BC. Now, if the radius of the slot is gradually increased, the slot will become nearer and nearer to being straight, so that the linkage shown in Fig. 49, where the slot is straight, may be said to be the limiting case of the linkage shown in Fig. 48. This is the linkage which we have in the crank, connecting rod, crosshead and crosshead guides of a steam engine. The crank shaft corresponds to the pin A, the frame and guides

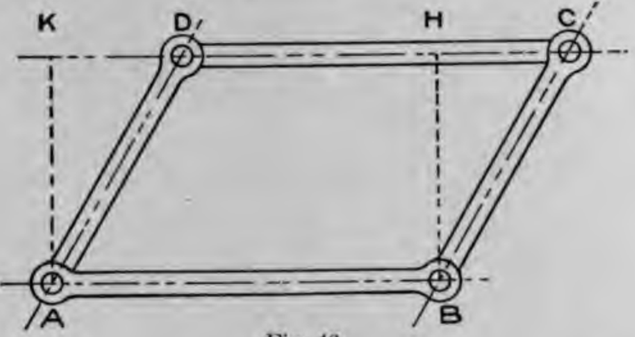


Fig. 46.

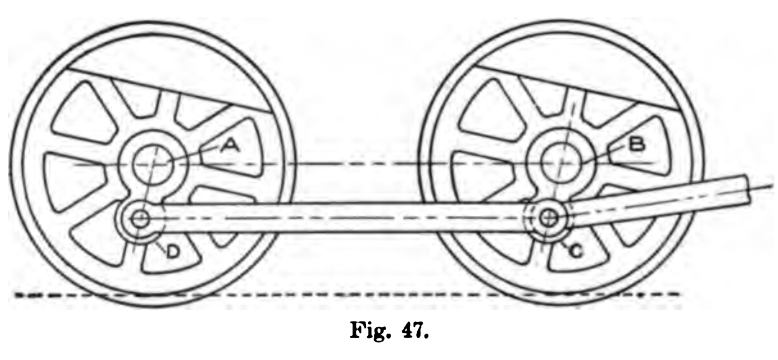


Fig. 47.

take the place of the slotted link AC, DC is the connecting rod, and AD the crank.

As there are many problems which may arise in connection with this linkage, particularly as applied to the steam engine, we will consider the most important.

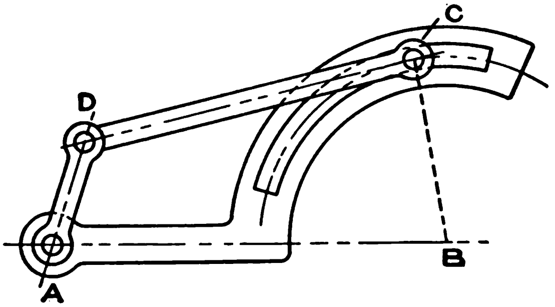


Fig. 48.

Fig. 50 shows the same linkage, the links being represented by their center lines only. AD is the crank, DC the connecting rod, C the crosshead and AC the center line through the crank shaft and the guides.

Suppose the crank has a length R and is making N revolutions per minute at a uniform speed, to find how fast the crosshead is moving at any given position of the crank.

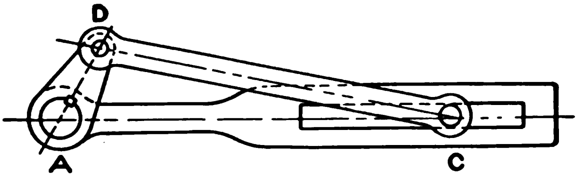


Fig. 49.

We will solve this problem partly graphically and partly by calculation. The first step is to find how fast the crank pin D is moving. For one turn of the crank, D travels through a distance equal to the circumference of a circle whose radius is R, that is, a distance of $2\pi R$. If the crank turns N times per minute the velocity of D must be $2\pi RN$. Knowing the value of R and N, for any particular case we can substite in this formula and find the actual velocity of D. Next draw the linkage at a convenient scale, in the position in which it is desired to find the velocity of C. Draw D*d* perpendicular to AD and make its length represent at a convenient scale (not necessarily the same scale as was used for the links) the calculated velocity of D. This represents the actual velocity and direction of motion of the end D of the connecting rod at the instant under consideration. Now resolve the velocity D*d* into its components, along and at right angles to DC, by prolonging the

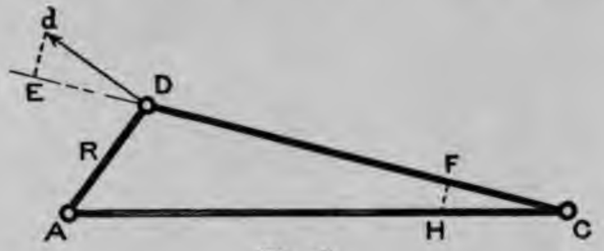


Fig. 50.

line DC and drawing *d*E perpendicular to it. The component DE is the only one which has any effect on the motion of the point C. We have already learned that the motion of the two ends of a rod must have their components along the rod equal, therefore lay off from C, CF = DE. The actual motion of C is along the line CA, and, as CF is one component of the motion, the other component

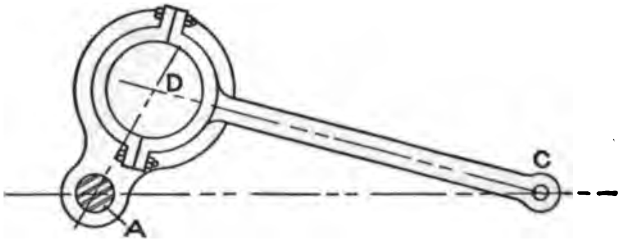


Fig. 51.

must be perpendicular to CF, therefore draw FH perpendicular to CF and meeting CA at H. Then CH is the velocity of point C at the same scale at which D*d* was drawn.

Eccentric. The eccentric and eccentric-rod linkage is in principle the same as the crank and connecting rod. To trace out the connection between the two, let us consider the crank and connecting rod shown in Fig. 51. Here the crank pin D is large and comes almost to the center of the shaft A. By increasing still further the diameter of the pin D, so that it will take in the shaft, as shown in Fig. 52, we obtain the eccentric.

Considering again the crank and connecting rod linkage: Suppose that in Fig. 53 a force F is applied at the crank pin D in a direction perpendicular to the center line AD; then the pressure which would be exerted by the slide C could be found by the same principle which we have used in previous cases, namely, the forces are inversely proportional to the velocities. Let F be the force at D, and P the pressure at C. Assume any velocity of the point D and represent this at some scale by the line D*d* perpendicular to AD. Then find the velocity CH of the point C along the line AC, in the same manner as in Fig. 50. The value of CH can be measured off at the same scale at which D*d* was drawn. Then

$$\frac{F}{P} = \frac{CH}{Dd} \qquad (18)$$

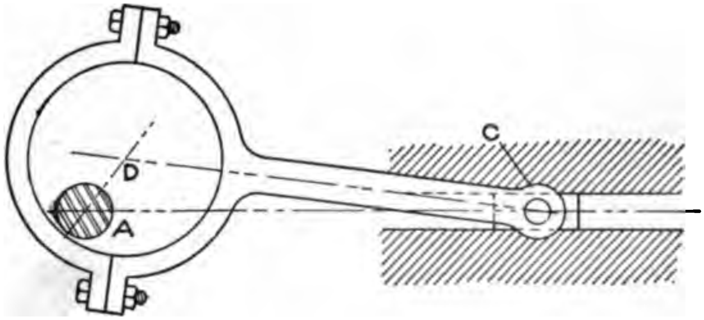


Fig. 52.

from which, if one of the quantities F or P is known, the other may be found.

If the value of CH is found for various positions of AD, keeping D*d* constant, it will be seen that the nearer AD comes to coinciding with AC, the smaller CH becomes, and from equation (18) it will appear that the smaller CH is, the greater P becomes with relation to F. The above discussion will hold true if the force acts in the direction D*d* or in the opposite direction.

The linkage used in this way to effect pressure at *c* by a force on D is known as the *toggle joint*, and is used with more or less modification in several kinds of machinery, such as punching machines, brakes on the drivers of a locomotive, etc. The force need not be applied at D, but may be applied at some other point on AD, or on some piece rigidly connected to AD but making an angle with it. This is shown in Fig. 54. Here the force is applied at E, and we can find the force at C by the same principle as before: The force at C is to force at E inversely as the velocities of C and E. The only difference is in finding the velocity of C. Assume a velocity for E, as Ee. Then

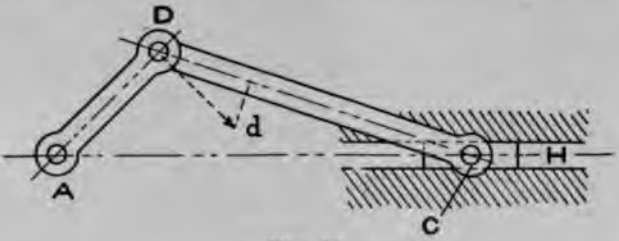


Fig. 53.

$$\frac{\text{Velocity E}}{\text{Velocity D}} = \frac{\text{A E}}{\text{A D}} \qquad (19)$$

from which the velocity of D may be found; the rest of the solution would be the same as for Fig. 53.

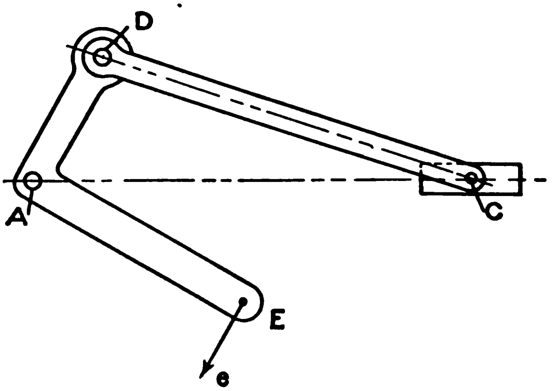


Fig. 54.

These problems may be solved by another and perhaps somewhat shorter method, but, as this would involve the resolution of forces, which have not yet been taken up in detail, we will confine ourselves to the above method.

QUICK RETURN MOTIONS.

In various kinds of machinery, particularly machine tools, it is desired to move a piece backward and forward; the forward motion being slow and the return motion more rapid. Take for example the shaper; as the tool when moving forward is cutting metal, it should go slowly and steadily, but after the cut is made it is desirable to get the tool back ready for its next stroke as quickly as possible. Many different devices are used to accomplish this result.

If in Fig. 45 we replace the connecting rod DC by a slot in the link BC, we get the linkage shown in Fig. 55. A and B are the fixed centers, AD is the driving crank (which usually turns with uniform speed), BD is the slotted crank and to some part of BD a link or some other piece is connected by means of which the tool is driven. Two distinct mechanisms are formed, depending upon the relative lengths of the links. If the proportions are such that a circle drawn around the center A, with radius AD, falls outside the center B, as shown in Fig. 56, we have what is known as a Whitworth quick return motion. Here the slotted crank makes one complete revolution for each complete revolution of AD, but its speed is not uniform. In this figure, a connecting rod PT is represented as attached to a point P on the slotted link. The other end of this connecting rod moves the tool holder T along the straight line BT. When the linkage is in the position shown, T is in its extreme right-hand position, and it will be in its

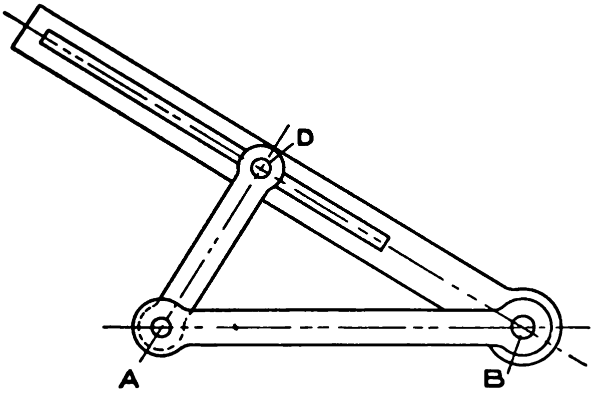


Fig. 55.

eft-hand position when BP occupies the position BP_1. in tu g BP through this angle (180°), AD has turned through the an L. In returning BP to its right-hand position again, AD ha o turn through the angle M only. Now, since AD turns wi form speed and since angle M is less than angle L, T make stroke from left to right in less time than was required to move from right to left. The time of advance and time of return are in the ratio of angles L and M. If the length of the crank AD and the ratio of time of advance to return are known the distance AB may be found as follows:

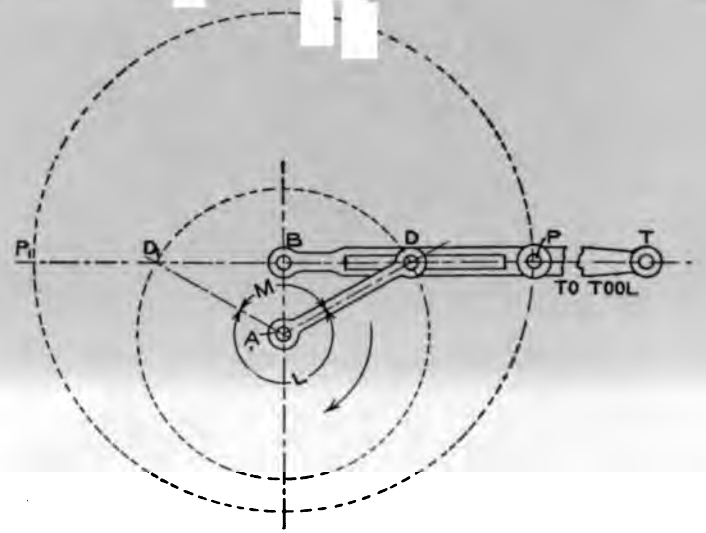


Fig. 56.

With A as a center and AD as a radius, draw a circle and divide the circumference by the points D and D_1 so that angle L may bear the same ratio to angle M that the time of advance bears to the time of return. Join D and D_1 and from A draw a line perpendicular to DD_1, meeting it at B, which will be the required center for the driven crank.

The distance BP governs the length of the stroke of the tool, so that by varying the position of P the length of the stroke may be varied.

If the proportions of the linkage are such that a circle drawn with A as a center and a radius AD comes inside the point B, [illegible]s, if AD is less than AB, we have what is known as a swinging block linkage. Fig. 57 shows this form of quick return motion. The piece which drives the tool is attached to the slotted link at P, which may be anywhere along the link. The linkage is shown at the extreme right of its stroke, the point D being at the point where the center line of the slot is tangent to the circle drawn with center A and radius AD, (that is, the length of the driving crank). AD_1 is the corresponding position of the crank

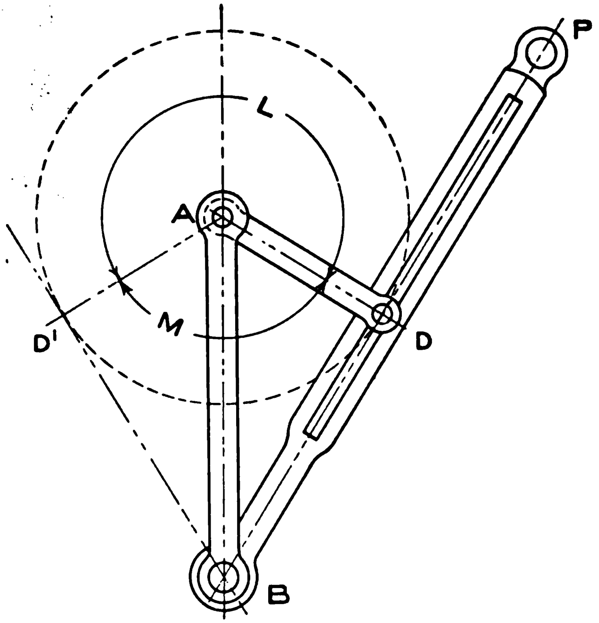


Fig. 57.

at the other extreme of the stroke. The time of advance is to the time of return as angle L is to angle M, as in the case of the Whitworth quick return. If the ratio of advance to return and the length of AD are known, the position of B may be found by drawing the circle with center A and radius AD, and on this circle finding points D and D_1 such that the angles L and M shall have the required ratio. Then draw DB and D_1B tangent to the circle at D and D_1 respectively, meeting each other at B, which is the required center for the driven crank.

GEARING.

ft B, Fig. 58, has fastened to it a disc with smooth cir- , the disc being in contact at the point P with another ft A, the rotation of one shaft will cause the other to rot provided there is sufficient friction between the two surfaces to prevent slipping. According to the principles which we have already learned, the following equation will hold true:

$$\frac{\text{Revolutions per minute of A}}{\text{of B}} = \frac{\text{B P}}{\text{A P}}$$

In practice, the n not be sufficient to be relied upon, so that discs having upon their circumference are used, instead of the plain discs. discs or wheels thus formed are called gears. The teeth may have any one of several forms, and the gears may connect shafts which are parallel, intersecting at some angle, or neither parallel nor intersecting. Two gears such as shown in Fig. 59, where the shafts are parallel and the teeth on the circumference are parallel to the axis of the gear, are called **spur gears.**

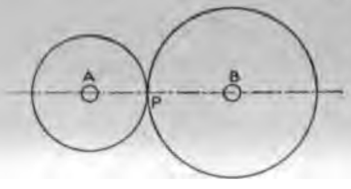


Fig. 58.

The two dot and dash circles drawn about the centers A and B and in contact at P correspond to the two discs of Fig. 58, and the gears may be said to be derived from these circles, which are called the **pitch circles.** The diameters of these circles are called the **pitch diameters** of the gears. The point P, where the two pitch circles touch each other, is called the *pitch point.* Circles drawn through the outer ends of the teeth are called the *addendum cirles,*. and circles drawn at the bottom of the teeth are called the *root circles.* These circles are indicated on the figure. That part of the tooth outlined between the pitch circle and the addendum circle, as PE, is called the **face** of the tooth, and that part between the pitch circle and the root circle, as PF, is called the **flank.** The radius of the addendum circle minus the radius of the pitch circle is called the addendum distance, or simply the *addendum.* The radius of the pitch circle minus the radius of the root circle is called the *root distance* or the *root.* The root is commonly made a little greater than the addendum, so that when two gears have their pitch circles in contact, if their teeth are of equal length they will not touch bottom, but will have some clearance. The distance from the center of one tooth to the center of the next, measured on the pitch circle, as GH, is called the **circular pitch,** or **circumferential pitch,** and is equal to the circumference of the pitch circle divided by the number of teeth.

In order to run together, two gears must have the same circular pitch. The number of teeth on two gears of the same pitch are proportional to the circumferences, and, consequently, to the diameters of their pitch circles; and as the speeds of the two shafts which are connected by a pair of gears are inversely proportional to the diameters of the pitch circles of the gears, the speeds must also be inversely proportional to the number of teeth.

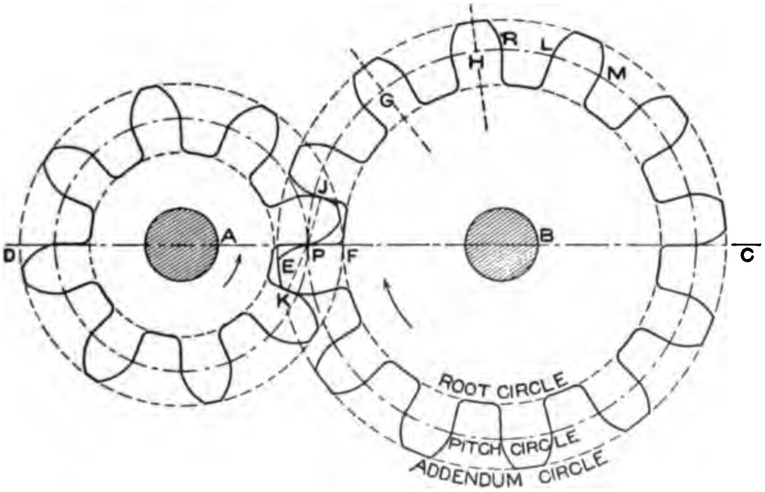
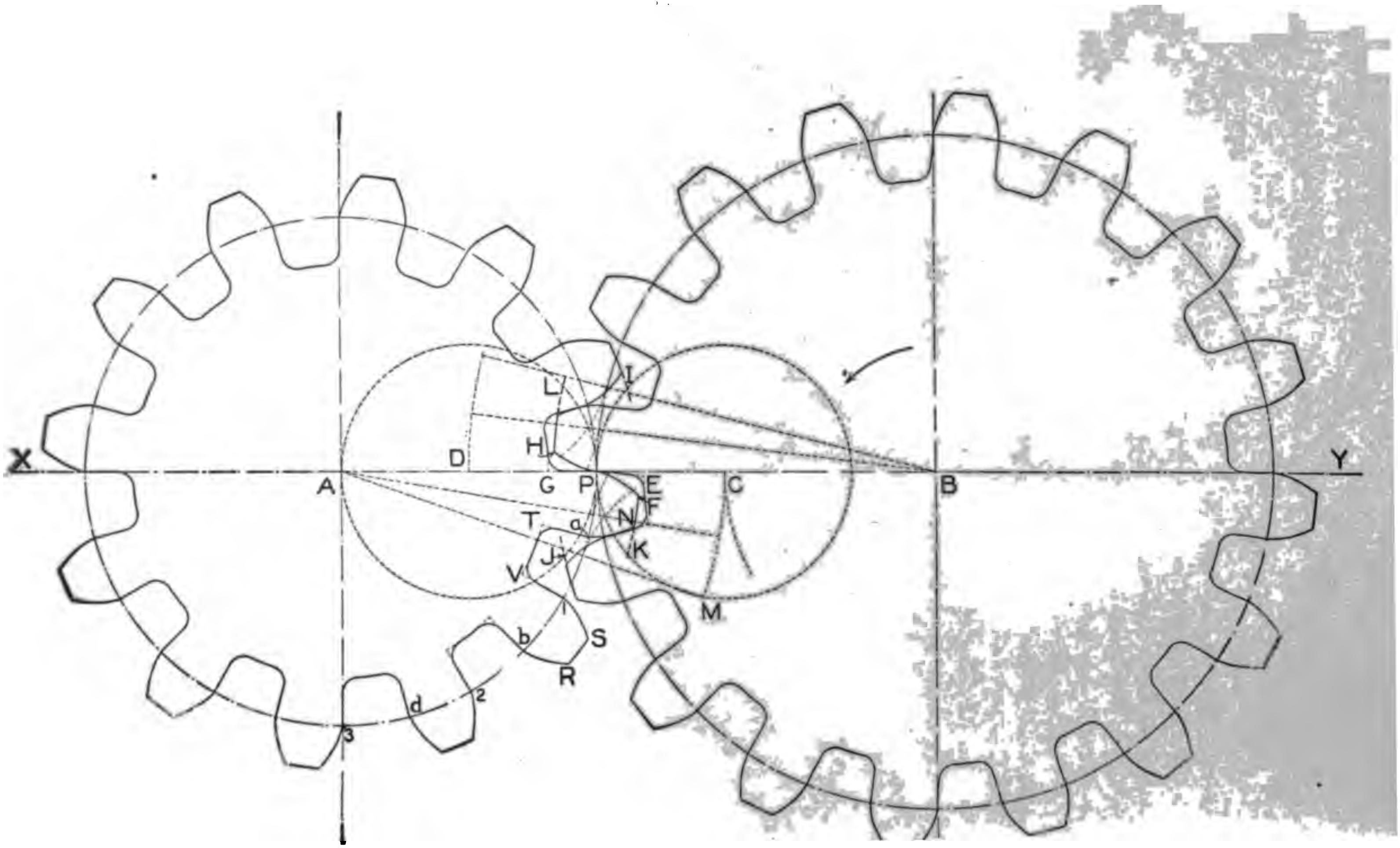


Fig. 59.

On rough gears the width of the tooth LM is made a little less than the width of the space RL, to allow for irregularity of construction. The difference in the width of the two is called the *back lash.*

Although the circular pitch is a term which is frequently used in connection with gearing, there is another kind of pitch which is often used. This is the **diametral pitch,** and is equal to the diameter of the pitch circle divided by the number of teeth, or, in other words, the amount of pitch diameter allowed for each


X
Y
A
B
C
D
E
F
G
H
I
J
K
L
M
N
P
R
S
T
V
a
b
d
2
3

tooth. The diametral pitch bears the same relations to the circular pitch that the diameter of a circle bears to its circumference; that is, the diametral pitch is equal to the circular pitch divided by π. In speaking of the pitch of a gear, instead of using the diametral pitch, which is often a fraction, it is customary to use only the denominator of the fraction. For example, if the diametral pitch is $\frac{1}{2}$ inch, it would be spoken of as a 2-pitch gear. This would be the same as saying that for every inch of pitch diameter there are two teeth.

Problems similar to the following often arise in this connection:

1. Given two gears, 4 pitch, having 12 teeth and 16 teeth respectively, to find their pitch diameters and the distance apart that their centers should be located, to run properly.

Since they are 4 pitch, their diametral pitch is $\frac{1}{4}$ inch and their pitch diameters will be their numbers of teeth multiplied by $\frac{1}{4}$, so that one would be $12 \times \frac{1}{4} = 3$ inches in diameter, and the other $16 \times \frac{1}{4} = 4$ inches in diameter. The distance on centers will be the sum of their pitch radii $= \frac{3}{2} + \frac{4}{2} = 3\frac{1}{2}$ inches.

2. Given two gears, 8 pitch, having diameters 6 and 10 inches respectively, to find the number of teeth.

The expression "8 pitch," besides meaning that the diametral pitch is $\frac{1}{8}$ inch, means that there are 8 teeth for every inch of diameter, so that one gear will have

$$8 \times 6 = 48 \text{ teeth}$$

and the other $8 \times 10 = 80$ teeth.

Referring again to Fig. 59: If gear A is driving the other gear in the direction indicated, there is a working point of contact between the teeth of the two gears at J and another at K, and as the gears turn and the teeth slide along each other, the point where a pair of teeth is in contact changes. If from the point of contact, as J, a line is drawn to the pitch P, the tooth curves should have such form that this line is normal to both curves at J; that is, PJ should be perpendicular to a line drawn tangent to both curves at J. This condition should hold, wherever the point of contact may be, in order that the gears may run smoothly.

There are two kinds of curves which are commonly used for the outlines of gear teeth, and which fulfill the above conditions.

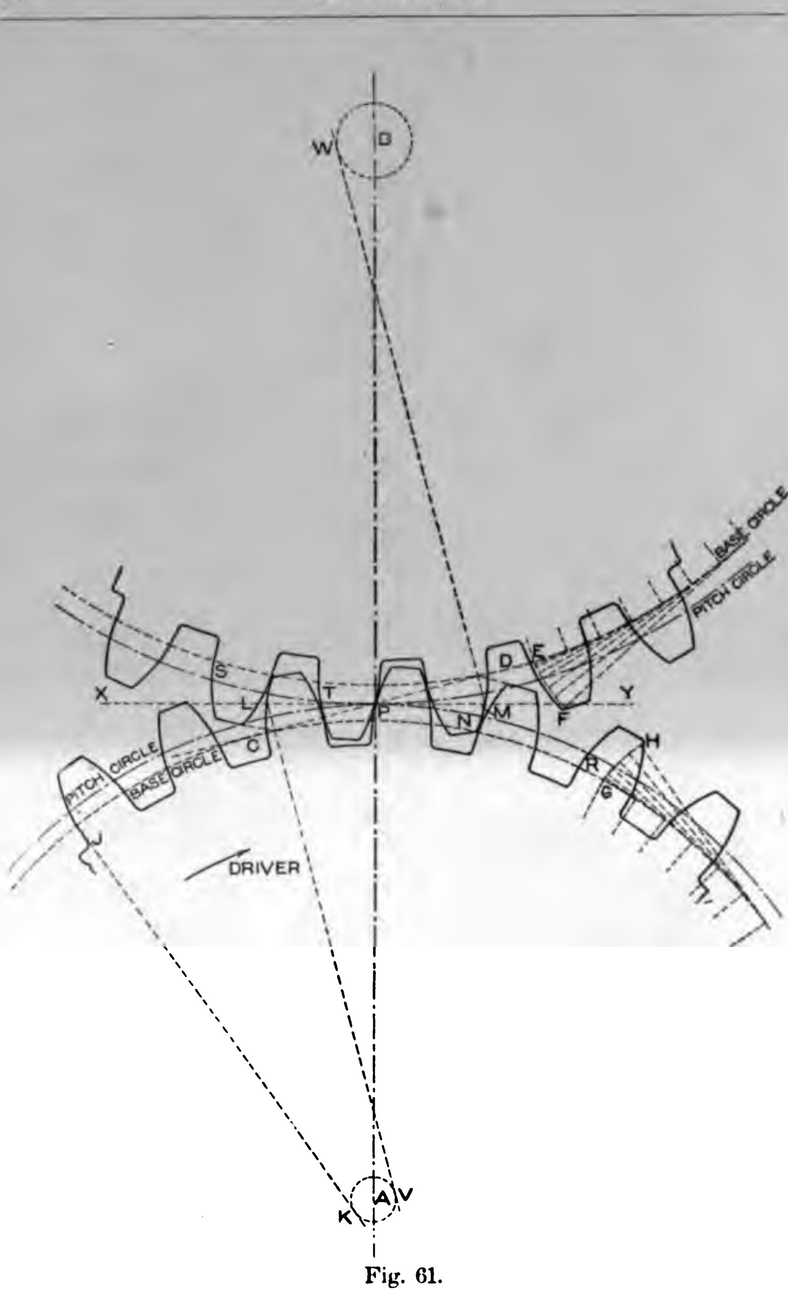

W
B
BASE CIRCLE
PITCH CIRCLE
D
E
S
X
T
L
P
N
M
F
Y
C
H
R
G
PITCH CIRCLE
BASE CIRCLE
J
DRIVER
K
A
V

Fig. 61.

These are the **involute** and the **epicycloidal** curves. Fig. 60 shows a pair of gears with epicycloidal teeth and Fig. 61 shows parts of two gears with involute teeth. The construction for getting the tooth outlines is shown in the figures, but as this properly comes under the subject of drawing, and is not essential to an understanding of gears in general, it will not be explained here.

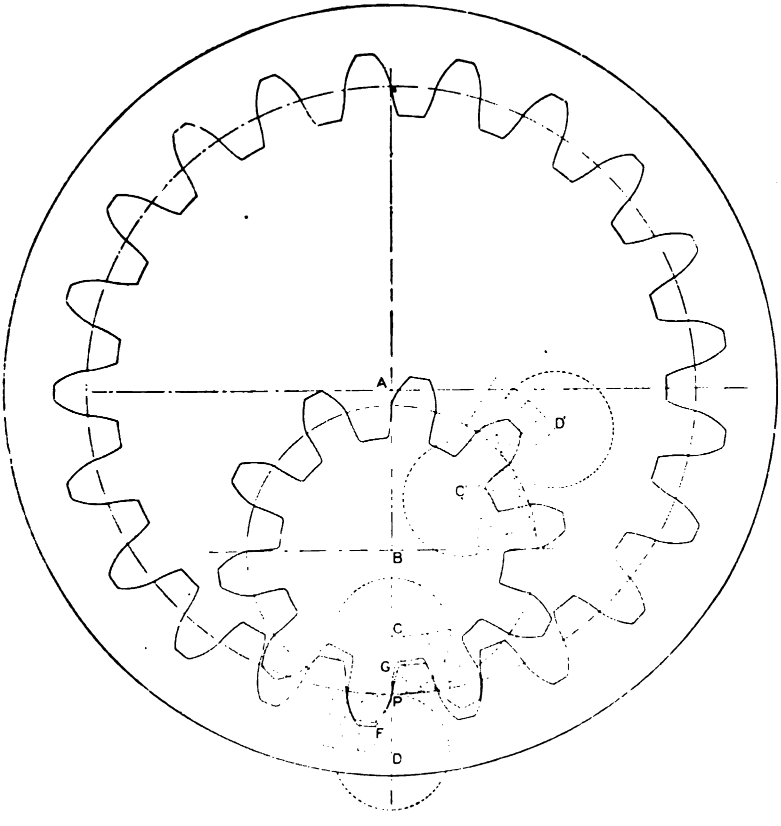


Fig. 62.

Annular Gears. An annular gear is a ring with teeth on its inside edge. Fig. 62 shows such a gear with center at A, meshing with a small spur gear called the pinion.

Rack and Pinion. A rack is a gear whose pitch line is a straight line instead of a circle. Fig. 63 shows an epicycloidal rack in gear with a pinion.

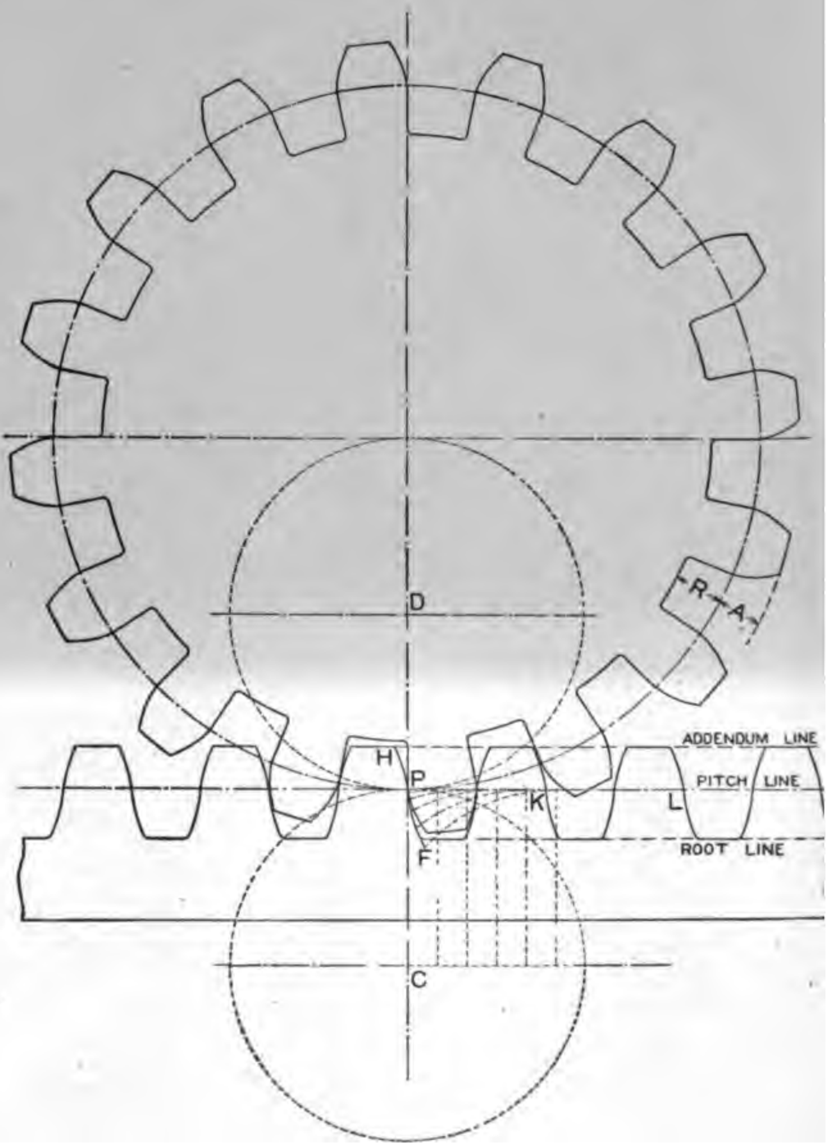


Fig. 63.

Bevel Gears. When two shafts whose axes intersect are to be connected by gears, the gears commonly used are called bevel gears. The theoretically correct pitch surface of a bevel gear is a part of the sector of a sphere, but as the designing and making of such a gear is somewhat difficult, a cone is substituted for a sphere. Fig. 64 shows a pair of bevel gears connecting two shafts which are at right angles. O is the point where the center lines of the shaft intersect, OPA and OPB are the *pitch cones* of the gears, AP and BP the pitch diameters.

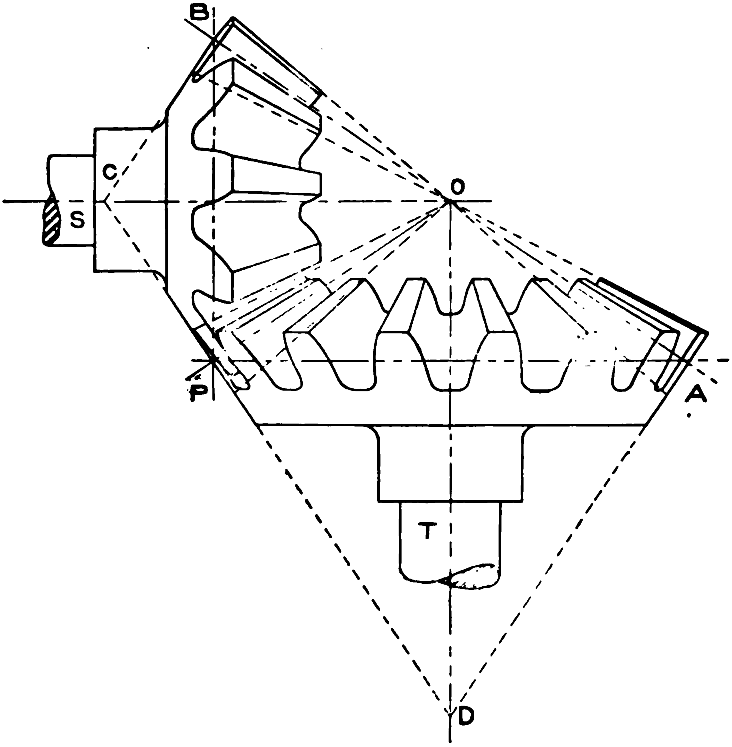
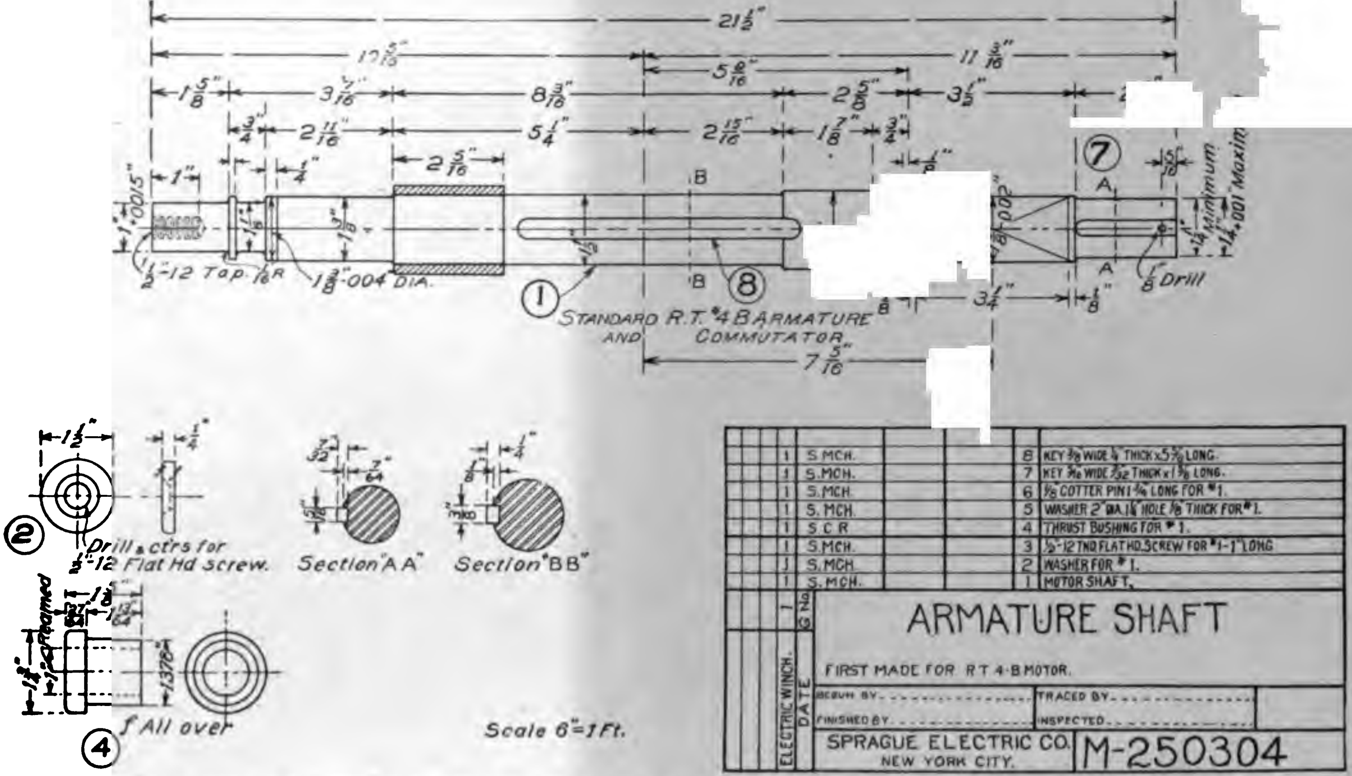


Fig. 64.

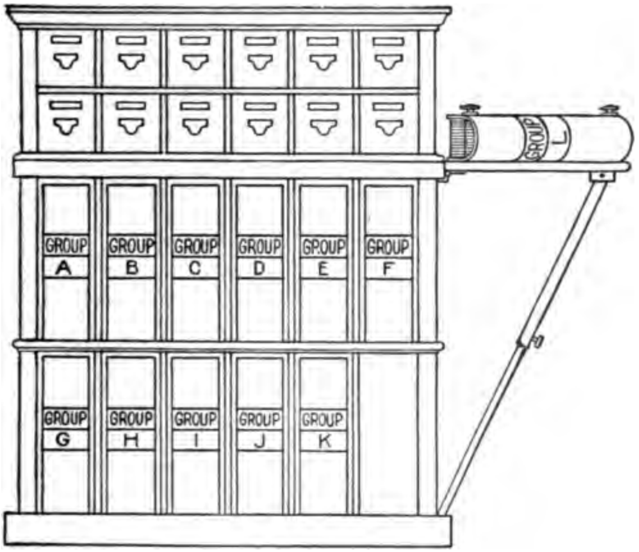
The speed of the shaft S is to the speed of the shaft T as AP is to BP. The teeth may be epicycloidal or involute, and the shafts may be at right angles or at some other angle.


21½"
12 5/16"
11 3/16"
5 9/16"
1 5/8"
3 7/16"
8 3/16"
2 5/8"
3½"
¾"
2 11/16"
5¼"
2 15/16"
1 7/8"
1"
¼"
2 5/16"
1"+.0015"
½"-12 Tap. 1/16R
1 3/8"-.004 DIA.
1 3/8"
1½"
1 3/8"-.002
B
B
① STANDARD R.T. #4 B ARMATURE AND COMMUTATOR.
⑧
7 5/16"
3¼"
⑦
A
A
5/16"
1¼" Minimum
1¼+.001 Maxim
⅛" Drill
⅛"
② Drill & ctrs for ½"-12 Flat Hd screw.
1½"
¼"
7/32"
7/64"
Section "A A"
⅛"
¼"
Section "B B"
④ f All over
1⅛"
1⅞" Reamed
1.378"
13/64"
Scale 6"=1 Ft.
1 S.MCH. 8 KEY ⅜ WIDE ¼" THICK x 5 5/8 LONG.
1 S.MCH. 7 KEY 5/16 WIDE 7/32 THICK x 1 5/8 LONG.
1 S.MCH. 6 ⅛ COTTER PIN 1 3/4 LONG FOR #1.
1 S.MCH. 5 WASHER 2" DIA. 1⅛ HOLE ⅛ THICK FOR #1.
1 S.C.R. 4 THRUST BUSHING FOR #1.
1 S.MCH. 3 ½"-12 THD FLAT HD. SCREW FOR #1-1" LONG
1 S.MCH. 2 WASHER FOR #1.
1 S.MCH. 1 MOTOR SHAFT.
G No. 1
ELECTRIC WINCH.
DATE
ARMATURE SHAFT
FIRST MADE FOR R.T. 4-B MOTOR.
BEGUN BY
TRACED BY
FINISHED BY
INSPECTED
SPRAGUE ELECTRIC CO. NEW YORK CITY.
M-250304

TYPICAL WORKING DRAWING OF ARMATURE-SHAFT MADE IN THE DRAFTING ROOM OF THE SPRAGUE ELECTRIC CO.

DRAFTING ROOM ORGANIZATION

It is always of interest to manufacturing engineers when anything additional to the subject of systematic commercial drawing is brought to their attention. The development of a universal drawing process or system sufficiently general to meet all practical needs of manufacturing concerns, will likely come about at some future time, and this may form part of the engineering curriculum in schools and colleges, much the same as bookkeeping has been taught in commercial colleges for years.



Cabinet Set Forming Portion of Part Drawing System.
Comprises, in the upper part, a card index; and in the lower part, a bound blue-print file containing records and drawings of finished material or parts.

The present is a period of standard manufacturing, and the tendency toward standardization is naturally growing, thereby creating a demand for different methods from those employed where the articles of manufacture were unsettled and undergoing ceaseless and uncertain changes. It is of course true that improvements in standard lines of manufacture will be continually required, but these changes take the form of revisions, to a greater or less extent, of designs that previously have been reduced to a fairly definite basis. The drawing office is where things are built on paper, and it is subject to a change of methods when approaching standard manufacturing as much as are the factory departments doing actual construction work.

To illustrate—the following list brings out a few of the essential features that usually appear for consideration in conducting a drawing office for developing specialized products:

1. The desirability of one uniform size of drawing sheet for all drawings.

2. The necessity of drawing parts independently of any mechanism to which they may belong, for the reason that any part is likely to be found available for use in the manufacture of a number of different mechanisms.

3. The necessity of knowing and being able to identify all parts by symbols.

4. A suitable system of drawing parts.

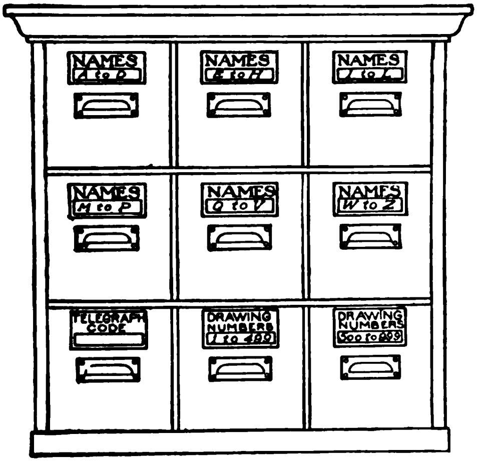
5. The necessity of classifying parts into groups or collections and grading them according to the primary operations that are required in forming them, or according to their elementary nomenclature or design.

6. As parts and constructional views cannot be shown on the same drawing, some means must be employed by draftsmen to specify and identify the parts that are involved in a general drawing.

7. Once typical general drawings have been made, how is it possible to avoid the delay and expense that are inevitably attached to redrawing practically the same thing for the many modifications arising from time to time?

Standard manufacturing may be looked upon as differing from special or miscellaneous manufacturing inasmuch as, under the former, parts take a systematic course from one set of machines to another until they finally become finished material.

The work of constructing or assembling the various parts to form a finished product, involves an entirely separate office. General drawings are of service principally where assembling is done, while the part-producing departments, on the other hand, require but those drawings that give working dimensions of parts. It is therefore seen that, so far as the uses of drawings are concerned, there is no occasion for showing parts associated with the finished mechanism, even were it possible to do so. Moreover, the fact that any single part may be found available in a variety of places, suggests the principle of showing parts collectively as a body of things having individual entity; and, if they are to be thought of as associated in some manner, it seems preferable to regard then as some group or collection. Where numerous parts are involved, the idea of drawing each of them separately on an independent sheet—which is a very general practice—incurs the disadvantage of a great collection of small sheets, whereas, by the use of a no less convenient but larger sheet, their number may be materially reduced by placing five to seven or more part views on the one drawing, arranging them, of course, according to their respective groups. One uniform size of drawing sheet can be used, which is of great advantage in filing and binding blue-prints for circulation.



Section of Cabinet Set for Finished Products.

Contains material record list cards arranged alphabetically under names of mechanism, general view drawing numbers, and telegraph code for drawing office reference.

Symbols. Symbols for parts usually take the form of numbers, with characters or letters annexed which signify the association of the parts. Each and every part is numbered in numerical sequence; and in the present instance, letters may be annexed which signify the group of which the part is a member, and the groups established according to the basic operations by which they are first formed. This is illustrated by the following list:

Cast Metal Parts.—*Group Symbol*, A.

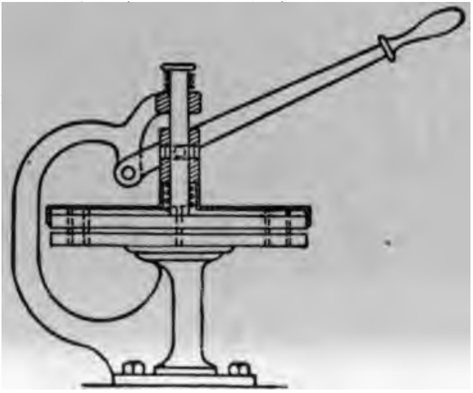
All parts originally formed by moulding or casting, and which are not magnets.

Sheet Metal Parts, Die Formed, etc.—*Group Symbol, B.*

All parts originally formed from sheet metal by puncturing, shearing, spinning, stamping, etc., and which are not magnets.

Machine-Formed Parts.—*Group Symbol, C.*

All metal parts machine-formed in lathes, shapers, milling machines, screw machines, threading and tapping machines, etc., such parts being made from raw material in the shape of rods, bars, tubes, plates, etc., and which are not magnets.



Trimmer and Punch-Press.

One advantage in employing a single standard size of sheet for part drawings is that the blue-prints can be machine-trimmed by a lightly constructed punch-press, which at the same time will pierce the holes for binding.

Magnets.—*Group Symbol, D.*

Cores of electro-magnets, armatures, pole-pieces, and shoes, frames, permanent magnets, shells, yokes, etc.

Insulators.—*Group Symbol, E.*

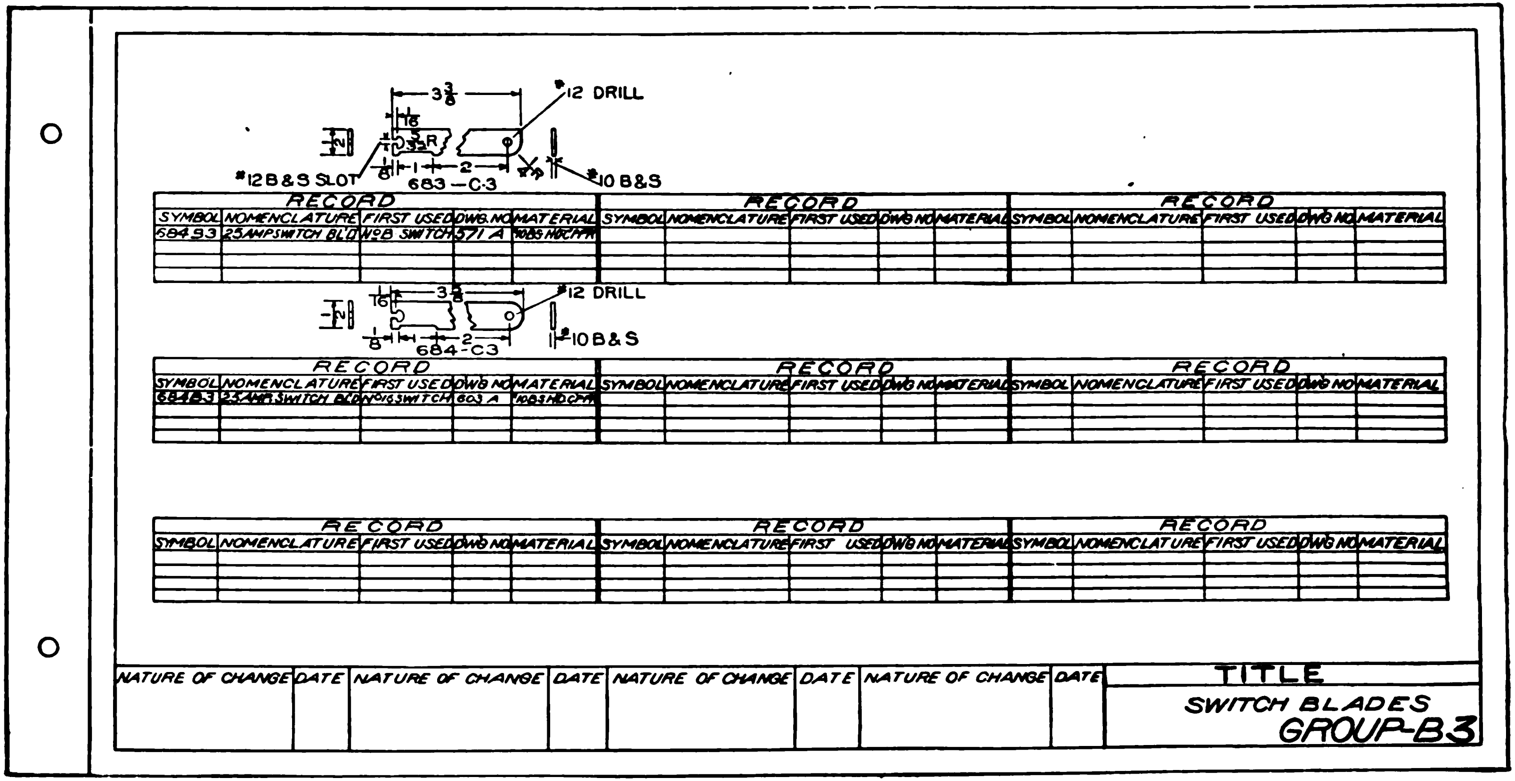
Tubes, strips, bushings, collars, handles, knobs, etc., of porcelain, glass, rubber, fiber, wood, paper; fabrics or parts made of other material for insulating purposes.

Coils.—*Group Symbol, F.*

Electro-magnet coils, resistance coils, condenser coils, or current-carrying coils of any nature; to comprise only the coil governed by its winding measurements, size of wire, number of turns, resistance, grade of insulation, and material wire is made of.

Forged or Wrought Parts.—*Group Symbol, G.*

All parts such as hooks, rivets, rings, wire springs, which are made of wire



RECORD					RECORD					RECORD				
SYMBOL	NOMENCLATURE	FIRST USED	DWG. NO	MATERIAL	SYMBOL	NOMENCLATURE	FIRST USED	DWG NO	MATERIAL	SYMBOL	NOMENCLATURE	FIRST USED	DWG NO	MATERIAL
684 93	25AMP SWITCH BL'D	No B SWITCH	571 A	10BS HDCPR										

RECORD					RECORD					RECORD				
SYMBOL	NOMENCLATURE	FIRST USED	DWG NO	MATERIAL	SYMBOL	NOMENCLATURE	FIRST USED	DWG NO	MATERIAL	SYMBOL	NOMENCLATURE	FIRST USED	DWG NO	MATERIAL
684B3	25AMP SWITCH BL'D	No 16 SWITCH	603 A	10BS HDCPR										

RECORD					RECORD					RECORD				
SYMBOL	NOMENCLATURE	FIRST USED	DWG NO	MATERIAL	SYMBOL	NOMENCLATURE	FIRST USED	DWG NO	MATERIAL	SYMBOL	NOMENCLATURE	FIRST USED	DWG NO	MATERIAL

NATURE OF CHANGE	DATE	NATURE OF CHANGE	DATE	NATURE OF CHANGE	DATE	NATURE OF CHANGE	DATE	TITLE
								SWITCH BLADES GROUP-B3

Specimen Part Drawing.

and which are not resistance coils; supports, brackets, fixtures, and all such parts, which are hand-formed, forged, or wrought, and which are not magnets.

WOODEN PARTS.—*Group Symbol, H.*

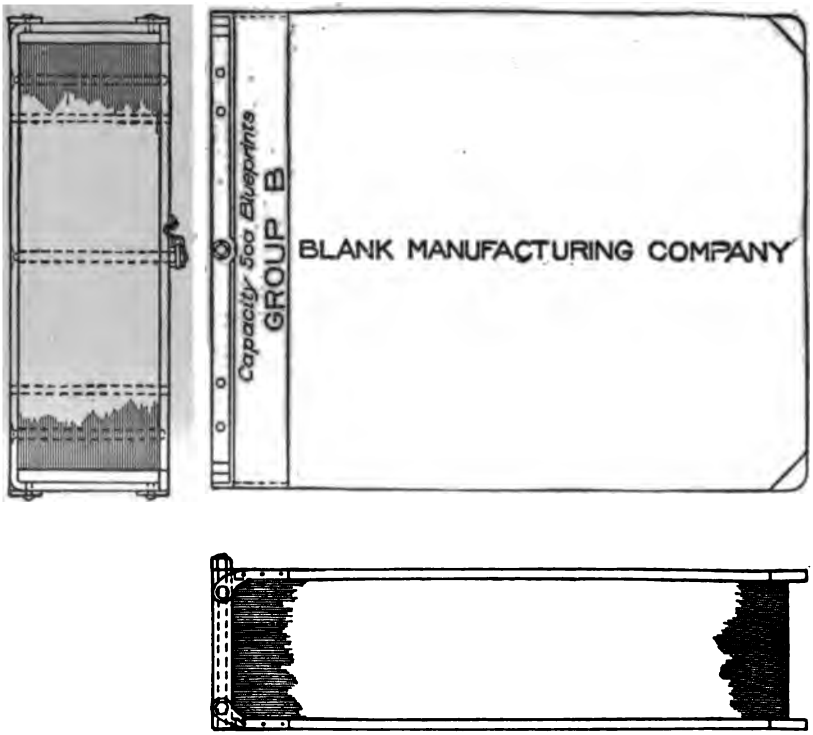
All wooden parts such as strips, pins, blocks, bases, moulding, ornaments, knobs, and brackets, which are not used for insulating purposes.

COMPOUND PARTS.—*Group Symbol, J.*

All parts consisting of more than one member, where it is necessary to join them to produce the part as completed material ready for assembling.

PURCHASED ARTICLES.—*Group Symbol, K.*

All articles such as locks, door or drawer knobs, fixtures, receptacles, and ornaments, which are compound parts, being purchased, not manufactured.

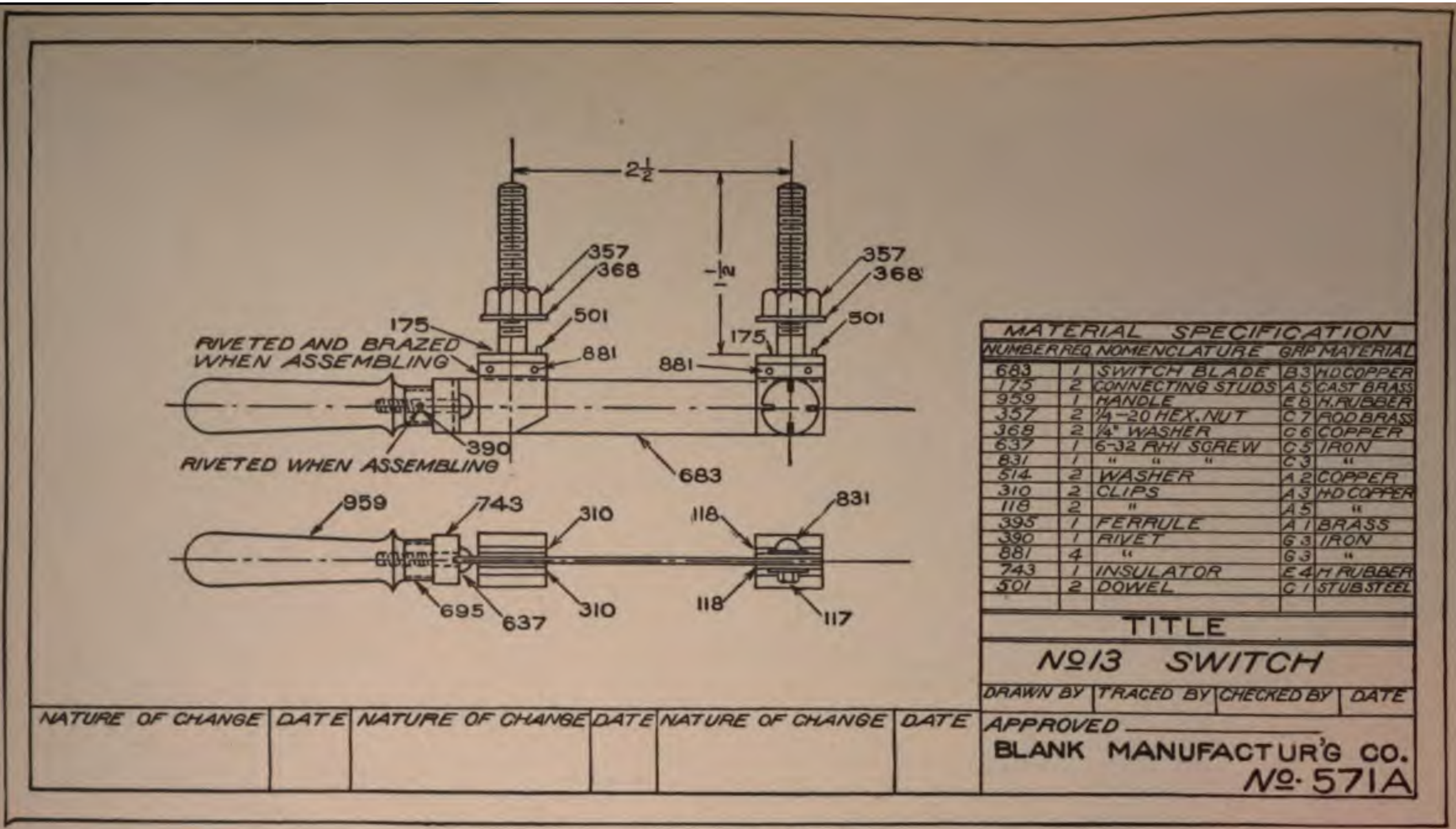


Detail of Blue-Print Binder Designed for Part Drawing System.

The binding clasp is independent of the covers, which are hinged and can be opened clear back, allowing free access to the prints. Any print can be removed or inserted at any point, and the binder conveniently rejoined by use of a combination key and guide.

The above classification enables an intelligent analysis of the parts to be made, placing them in their respective group order according to the directions or codifications given.

The drawings for each set exhibit a convenient number of part views, and the title of each sheet indicates the name and group



MATERIAL SPECIFICATION				
NUMBER	REQ.	NOMENCLATURE	GRP	MATERIAL
683	1	SWITCH BLADE	B 3	H.D. COPPER
175	2	CONNECTING STUDS	A 5	CAST BRASS
959	1	HANDLE	E 8	H. RUBBER
357	2	¼-20 HEX. NUT	C 7	ROD BRASS
368	2	¼" WASHER	C 6	COPPER
637	1	6-32 R.H. SCREW	C 5	IRON
831	1	" " "	C 3	"
514	2	WASHER	A 2	COPPER
310	2	CLIPS	A 3	H.D. COPPER
118	2	"	A 5	"
395	1	FERRULE	A 1	BRASS
390	1	RIVET	G 3	IRON
881	4	"	G 3	"
743	1	INSULATOR	E 4	H. RUBBER
501	2	DOWEL	C 1	STUB STEEL

TITLE

Nº 13 SWITCH

DRAWN BY	TRACED BY	CHECKED BY	DATE

APPROVED

BLANK MANUFACTUR'G CO.

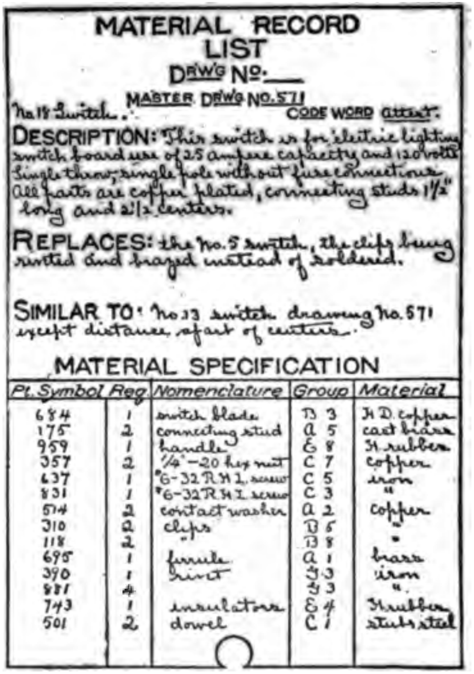
Nº 571A

NATURE OF CHANGE	DATE	NATURE OF CHANGE	DATE	NATURE OF CHANGE	DATE

Specimen General View Drawing.

of the parts it contains. The sheets are numbered serially, beginning each set with *No. 1*, the number increasing by one for each successive addition. If, for illustration, the number portion of a part symbol is *368*, then, in order to signify its groups and still more its drawing, we might write *368A3*, which means that the part belongs to the *A* group (Cast Metal Parts), and is shown on the third drawing of the series.

Material Lists. Where articles of manufacture are repeatedly reproduced, as is the case in standard manufacturing, and where, as often occurs, they are, for various reasons, not made in all cases just exactly alike, there is involved the question as to how far the reproduction of general view drawings should be carried. A record at least is necessary of each article, just as it is built. The old and familiar but serviceable plan of employing material lists, developed through the use of part symbols, etc., serves admirably in combination with a typical or master drawing. Such lists enumerate the various parts used in each mechanism;



MATERIAL RECORD
LIST
DRWG NO.___
MASTER DRWG NO. 571
No. 18 Switch. CODE WORD attest.

DESCRIPTION: This switch is for electric lighting switch board use of 25 ampere capacity and 120 volts single throw, single pole without fuse connections. All parts are copper plated, connecting studs 1½" long and 2½ centers.

REPLACES: the No. 5 switch, the clips being riveted and brazed instead of soldered.

SIMILAR TO: No. 23 switch drawing No. 571 except distance apart of centers.

MATERIAL SPECIFICATION

Pt. Symbol	Req.	Nomenclature	Group	Material
684	1	switch blade	B 3	H. D. copper
175	2	connecting stud	A 5	cast brass
959	1	handle	E 8	H. rubber
357	2	¼"–20 hex nut	C 7	copper
637	1	#6-32 R.H.I. screw	C 5	iron
831	1	#6-32 R.H.I. screw	C 3	"
514	2	contact washer	A 2	copper
310	2	clips	B 6	"
118	2	"	B 8	"
695	1	ferrule	A 1	brass
390	1	rivet	G 3	iron
881	4		G 3	"
743	1	insulators	E 4	H. rubber
501	2	dowel	C 1	stubs steel

and when the construction changes, it must occur through a change in the combination of parts. Therefore, when the parts are enumerated there can be no mistake about the construction. To illustrate the use of such lists, let us assume the instance of a switch which is represented by a general drawing and called the "No. 13 Switch." Occasion later arises for a modification, say in the distance between stud centers. This will require a different blade, which is practically the only difference between the switches. The material record list shown in the accompanying illustration fully serves the purpose, as it reveals and identifies the component parts which, accompanied with a master drawing, furnish complete manufacturing data.

The "Material Specification" portion of the record card is in form a duplicate of the material list appearing in general drawings, being used for the same purpose—that of identifying the parts involved in a convenient tabulation.

REVIEW QUESTIONS.

PRACTICAL TEST QUESTIONS.

In the foregoing sections of this Cyclopedia numerous illustrative examples are worked out in detail in order to show the application of the various methods and principles. Accompanying these are examples for practice which will aid the reader in fixing the principles in mind.

In the following pages are given a large number of test questions and problems which afford a valuable means of testing the reader's knowledge of the subjects treated. They will be found excellent practice for those preparing for College, Civil Service, or Engineer's License. In some cases numerical answers are given as a further aid in this work.

REVIEW QUESTIONS

ON THE SUBJECT OF

FORGING

1. Make a sketch and show all dimensions of a hoisting hook for a load of 2,000 lbs.

2. What is the essential difference between tool steel and wrought iron?

3. What is shrinking?

4. What three materials are commonly used in forge work?

5. Give two methods of measuring the amount of stock required to make a scroll.

6. How much would the crank shaft shown in Fig. 82 weigh, before any machine work was done on it, if $\frac{1}{4}''$ be allowed for finish on all surfaces where called for?

7. How is a lead bath used, and what is the advantage in tempering?

8. What length of stock, $\frac{1}{2}''$ in diameter, is required to make a ring 3″ inside diameter? No allowance for welding.

9. What is meant by the term "allowance for finish"?

10. What is annealing?

11. How does brazing differ from welding?

12. What is the tuyere?

13. If two plates are to be riveted together as tightly as possible, should heavy or light blows be used?

14. What is meant by "the hardening heat?"

15. Make a sketch showing what dimensions the forging shown in Fig. 78 would have if $\frac{1}{4}''$ finish were allowed all over.

16. Of what does welding consist?

17. What precautions must be taken when forging a round bar to a point?

18. Three pieces of tool steel are heated to the hardening heat; the first is cooled in water, the second in oil, and the third is allowed to cool in the air. What will be the relative hardness? Why?

19. How are tongs fitted to work?

20. Make a sketch and show all dimensions of a hexagonal head bolt $\frac{3}{4}$" x 8".

21. How is the final hardness of steel affected by the rate of cooling?

22. If a tap is broken off in a piece of work, the work is wanted in a hurry, and it is necessary to anneal the piece, how can the annealing be done?

23. What is brazing?

24. How much would an anvil marked 3 – 2 – 10 weigh?

25. Why are scarfs used in welding?

26. Why are springs hardened and tempered in oil?

27. Why is borax a better flux than sand?

28. What are the characteristics of a good forge coal?

29. What determines the size of the grain in hardened steel?

30. What is the down draft system?

31. What is meant by scarfing?

32. What is meant by clearance on lathe tools?

33. What is a flux, and why is it used in welding?

34. How are steam hammers rated?

35. Why should the ends of pieces to be welded, be upset?

36. (a) What do you understand to be meant by an oxidizing fire? (b) What do you understand to be meant by a reducing fire?

37. In making an S wrench, which is preferable; to forge the jaws separately and then weld on the handle, or to cut the jaws from a solid piece of metal and draw down the material between them to the proper size for the handle?

38. Explain the method of making a ladle shank in such a way that no welds are necessary in its construction.

39. Describe with sketches the so-called commercial method of forging a crank shaft.

REVIEW QUESTIONS

ON THE SUBJECT OF

MECHANISM.

---

1. An engine makes 280 revolutions per minute. If the stroke is 16 inches, what is the linear velocity of the crank pin in feet per second?

2. The pitch of a jack screw is $\frac{1}{4}$ inch. The length of the bar is 4 feet. What weight can be lifted if the force applied at the end of the bar is 148 pounds?

3. A worm of double thread meshes with a worm wheel having 64 teeth. How many revolutions per minute must the worm have to turn the wheel 2 times per minute?

4. A lever safety valve has a lever 30 inches long. The weight hung on the end weighs 24 pounds. If the valve is $4\frac{1}{2}$ inches from the fulcrum and has an area of $3\frac{1}{4}$ square inches, at what pressure per square inch will it blow off?

Neglect weight of valve, spindle and lever.

5. Define circular pitch. Diametral pitch.

6. If a gear has 20 teeth and it is 6 pitch, how far will the rack move in $2\frac{1}{3}$ revolutions of the gear?

7. Find the piston speed in feet per minute of an engine making 5.4 revolutions per second, the stroke being 18 inches.

8. Two gears mesh with each other. They are 8 pitch. If they have 40 teeth and 68 teeth, respectively, what are the diameters and how far apart should the centers of the shafts be placed?

9. The pitch circle of an annular gear is 36 inches in diameter. The spur gear meshing with it is 8 pitch and has 24 teeth. How many revolutions must the spur gear make to turn the annular gear 13 times per minute?

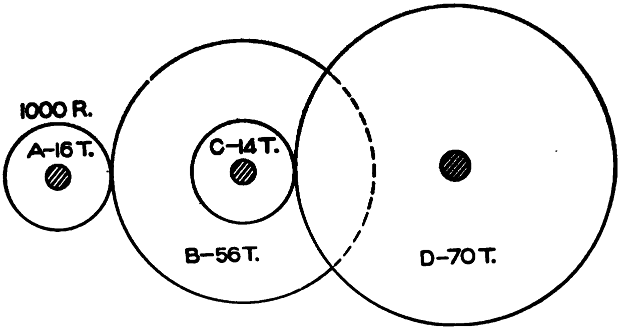
10. A lever is 26 inches long. A weight of 20 pounds is hung on one end. The distance of this weight from the fulcrum is 11 inches. What power will be necessary to raise the weight if the distance from the fulcrum to the power is 15 inches?

11. Describe the Whitworth quick-return motion.

12. A worm of single thread is in mesh with a worm wheel having 36 teeth. A crank of 16 inches radius is attached to the worm and a drum 10 inches in diameter is fastened to the worm wheel. How fast will the weight rise if the crank is turned 40 times per minute?

13. Suppose the press shown in Fig. 32, page 31, has a hand wheel 16 inches in diameter. The pitch $P = \frac{1}{4}$ inch and pitch $p = \frac{1}{6}$ inch. If 80,000 pounds are to be lifted what force must be applied to the hand wheel?

14. Describe some form of friction clutch.



15. In the train of gears shown, A is attached to the shaft of a motor and makes 1,000 revolutions per minute. How many revolutions per minute will gear D make?

16. If the linear velocity of the rim of a fly wheel is limited to a mile a minute, how many revolutions are allowable if the fly wheel is $7\frac{1}{2}$ feet in diameter?

17. A locomotive is running at the rate of 50 miles per hour. The drivers are 6 feet in diameter and the linear velocity of the crank pin is 24.44 feet per second. What is the length of stroke?

NOTE. The stroke=the diameter of crank-pin circle.

18. What is the pitch of a screw that advances 3 inches in 24 revolutions?

19. What weight can be raised by the device described in question 12 if the force applied to the crank is 110 pounds?

GENERAL INDEX

[illegible]

Alloys [illegible]
[illegible]
Alternators [illegible]
in parallel [illegible]
in series [illegible]
Aluminum [illegible]
Aluminum steel [illegible]
Angle [illegible] IV [illegible]
Angular cutters I [illegible]
Annealing II [illegible]
box I 215
copper and brass IV 94
tool steel I 214
Annular gears IV. 529

Automatic [illegible]
Automatic [illegible]
Automobiles [illegible]
air [illegible]
air fans [illegible]
Anderson [illegible]
auxiliary [illegible]
balance gear [illegible]
bearings [illegible]
bodies of [illegible]
brakes [illegible]

Note.—For page numbers see foot of pages.

GENERAL INDEX

In this index the Volume number appears in Roman numerals I, II, III, IV, etc., and the Page number in Arabic numerals 1, 4, etc. For example, Volume IV, Page 327, is written IV, 327.

The page number of each volume will be found at the bottom of the page; the numbers at the top refer only to the section.

	Part	Page
verter lining	II.	358
s of steel	II.	364
	I.	284
mill	I.	300
s	I.	245
ge	I	401
	I.	272
s to center	I.	88
devator	III.	225
	III.	162
	II.	354
	II.	355
s circuits, meas-		
s of power in	III.	434
s motors	III.	466
s systems		
g of	III.	[illegible]
[illegible]	III.	[illegible]
[illegible]	III.	[illegible]
[illegible]	II.	[illegible]
[illegible]	II.	[illegible]
[illegible]	IV.	[illegible]
[illegible]	I.	[illegible]
[illegible]	II.	[illegible]
[illegible]	I.	[illegible]
[illegible]	IV.	[illegible]
[illegible]	I.	[illegible]
[illegible]	IV.	[illegible]

	Part	Page
Anvils	IV.	16
Appliances, automatic	II.	631
Approved apparatus and supplies	III.	637
Arbors	I.	262
eccentric	I.	259
mandrels	I.	262
milling machine	I.	260
Arc vs. incandescent system of lighting	III.	629
Arc lamps	III.	636
on low-potential circuits	III.	630
Arc light wiring	III.	513, 530
Armature		
balance of	III.	412
heating of	III.	451
Armor plate, Harvey process	II.	368
[illegible]	III.	476
[illegible]	I.	461
[illegible]	IV.	403
[illegible]	[illegible]	[illegible]

Part Page

- Automobiles
  - change-speed devices III, 118
  - clutches III, 129
  - connecting rods III, 101
  - crank case III, 104
  - crank shaft III, 102
  - cylinder of engine for III, 97
  - emergency seats III, 163
  - excess cooling III, 111
  - faulty compression III, 99
  - fittings III, 168
  - fly-wheel III, 103
  - foreign influence on III, 93
  - friction gear III, 124
  - front axle III, 141
  - galvanic cells III, 158
  - gimbal joints III, 136
  - history of III, 88
  - ignition III, 153
  - individual clutch III, 120
  - lamps III, 172
  - location of mechanism III, 165
  - lubrication III, 112
  - mechanical generators III, 159
  - motor, theory of III, 97
  - muffler III, 106
  - occasional experiments in III, 89
  - operation of III, 172
  - pioneers in manufacture of III, 90
  - piston III, 100
  - planetary gear III, 119
  - premature ignition III, 111
  - present types III, 94
  - pumps III, 160
  - radius rods III, 136
  - rear axle III, 140
  - shock absorbers III, 169
  - sliding gear III 121
  - steam decadence III. 92
  - steam vehicles III, 95
  - steering heads III, 142
  - tires III, 150
  - tops of III, 165
  - transmission III, 131
  - valve action III, 105
  - valve ports of motor III, 98
  - vaporizers III, 107

Part Page

- Automobiles
  - vehicle control III, 128
  - water cooling III, 113
  - wheels III, 149
- "Babbitt" metal II, 334
- Back firing III, 63
- Backing off by an eccentric arbor I, 327
- Back saw II, 21
  - exercise for II, 21
- Band saws II, 59
- Banking of blast furnace II, 342
- Bare wires III, 490
- Barrel core, making II, 453
- Basic process of steel, management of II, 365
- Beam compasses IV, 341
- Bearings
  - for automobiles III, 170
  - friction of III, 410
  - heating of III, 453
  - machine II, 325
  - materials for II, 334
  - problems on II, 334
- Bearings, brackets, and stands II, 324
- Belting I, 204
  - horse-power transmitted by II, 235
  - material of II, 237
  - speed of II, 237
  - strength of leather II, 235
- Belts II, 229
  - analysis of II, 229
  - initial tension in II, 238
  - practical modification of II, 234
  - problems on II, 239
  - theory of II, 231
  - width of, for hoists II, 183
- Bench, machinist's I, 38
- Bench miller I, 161
- Bending die I, 383
- Bessemer converter, blowing II, 356
- Bessemer steel II, 354
- Bessemer steel process I, 442
- Bevel I, 16; II, 37
- Bevel gears II, 280; IV, 531
  - patterns for II, 149
- Binders for cores II, 429
- Bits II, 44

Note.—For page numbers see foot of pages.

Part Page
Black prints, formula for IV, 404
Blacking for moulds II, 433
Blast for cupola II, 485
Blast for forge IV, 14
Blast furnace I, 422; II, 339
  banking of II, 342
  chemistry of II, 343
  materials used in II, 341
  operation of II, 341
Blast furnace gas III, 71
Blowing Bessemer converter II, 356
Blue-print solution, formula for IV, 404
Blue printing IV, 402
Boiler construction III, 229-261
  arrangement of plates and
    joints III, 244
  calking III, 260
  in detail III, 234
  flanging iron and steel
    plates III, 243
  materials for III, 229
  rivets and riveting III, 238
  staying III, 250
  testing machines III, 232
  testing materials in III, 231
  tubes III, 257
  welded joints III, 243
Boiler materials, strength of III, 233
Bolt cutter I, 68
Bolt header IV, 106
Bolts II, 303
  problems in II, 313
  table for strength of II, 308
  tap II, 312
  through II, 312
Boring holes I, 110
Boring tools I, 98
Bow pen and bow pencil IV, 336
Box annealing I, 215
Box jig I, 362
Brackets, machine II, 324
Brake for automobile III, 147
Brake for hoist II, 203
Brake-relief spring II, 209
Brake-strap bracket II, 209
Brass moulding II, 510
Brass work II, 503

Part Page
Brazing IV, 92
Bridge tramways II, 533
Brilliancy of illumination III, 528
Bronze II, 504
Brushes, copper commutator,
  care of III, 482
Buckets
  clam-shell II, 536
  grab II, 535
Bulldozer IV, 101
Bushings I, 358; III, 522
  removable I, 360
Cables, elevator III, 222
Calculation of stock
  for bent shapes IV, 32
  for forged work IV, 52
Caliper I, 21; II, 40
Caliper square I, 23
Calking boilers III, 260
Cams I, 180; IV, 506
  cylindrical IV, 511
  plate IV, 507
Caps and brackets for hoist II, 199
Carbon, effect on iron II, 345
Car-dumping machines II, 539
Case-hardening I, 221; II, 368; IV, 95
Cast iron II, 344
  bending of IV, 94
  malleable II, 346
  table of grades II, 345
Casting of iron I, 427
Casting ladle II, 359
Castings II, 346
  cleaning of II, 490
  defects on II, 414
  duplicating II, 443
  flaws in I, 507
  steel II, 495
Cementation steel II, 305
Center chisels I, 40
Center punch I, 12
Center square I, 17
Centering work I, 85
Centrifugal whirling of shafts II, 263
Chain links IV, 27
Charter gas engine III, 23
Chasing I, 121

Note.—For page numbers see foot of pages.

	Part	Page
Chemistry of blast furnace	II,	343
Chipping	I,	42
Chisels		
center	I,	40
diamond poin	I,	40
flat	I,	39
Chisels and gouges	II,	31
Chrome steel	II,	367
Chuck	I,	81
Chuck-drill	I,	51
Circuits		
grounding of	III,	495
various kinds of	III,	377
Circular pitch	IV,	525
Clam-shell buckets	II,	536
Clamp coupling	II,	302
Claw coupling	II,	302
Clearance holes	I,	283
Cleft or split weld	IV,	30
Clutches, friction	II,	293
Coal appliances	II,	531
grab buckets	II,	535
Coal gas	III,	65
Coal-loading machines	II,	540
Cold chisels	I,	201
Columns, pattern for	II,	152
Combination counterbores	I,	297
Commutator		
care of	III,	482
heating of	III,	449
Compass	IV,	332
Compass saw	II,	22
Compensators, starting	III,	404
Compound bending die	I,	384
Compound dynamo in parallel	III,	386
Compound-wound motors	III,	398
Concealed wiring	III,	515
Condensers	III,	297
jet	III,	300
of steam turbine	III,	340
surface	III,	297
Conduit wire	III,	517
Conduit wiring	III,	518
Conduits, insulated metal	III,	516
Cones		
stepped	IV,	492
taper	IV,	490
Connections of wires, diagrams of	III,	378
Constant-potential motors	III,	409
Construction of boilers	III,	229
Constructive mechanics	II,	168
Cooling towers	III,	303
Cooper Hewitt light	I,	466
Copper	II,	371, 504
cupola smelting for	II,	372
extraction of	II,	371
properties of	II,	375
refining of	II,	373
Copper and brass annealing	IV,	94
Copper ores	II,	371
Core-box plane	II,	29
Core making	II,	388, 428
Core sand	II,	433
Cores		
binders for	II,	429
making	II,	388, 428
setting of	II,	439
Corliss engine	III,	294
Cornish pumping engine	III,	271
Cornish steam engine	III,	271
Cotters, machine	II,	320
Counterbores	I,	290
combination	I,	297
with inserted pilots	I,	295
Couplings	II,	299
clamp	II,	302
claw	II,	302
problems on	II,	303
Cranes	IV,	101
Crank and connecting rod	IV,	516
Crank shafts, forging of	IV,	58
Cranks		
multiple-throw	IV,	60
three-throw	IV,	61
Cross-arms	III,	503
Cross-sections, mechanical drawing	IV,	373
Crowning pulleys	IV,	488
Crucible steel	II,	353
Crucible steel process	I,	432
Cull poles	III,	501
Cupola mixtures	II,	480
Cupola smelting for copper	II,	372
Cupolas, fuel for	II,	485

Note.—For page numbers see foot of pages.

Part Page

- **Cupolas**
  - **mixtures for** II, 480
  - **operating of** II, 476
- **Current, measurement of** III, 426
- **Cut-out cabinets** III, 533
- **Cut-outs** III, 374
- **Cutters** I, 151
  - **end mills** I, 157
  - **formed** I, 155
  - **inserted-tooth** I, 155
  - **plain milling** I, 157
  - **side milling** I, 153
  - **spiral teeth** I, 152
- **Cutting speed of tools** I, 100
- **Cutting tools** I, 39
  - **center chisels** I, 40
  - **diamond point chisel** I, 40
  - **file** I, 43
  - **flat chisel** I, 39
  - **speed of** I, 100
- **Curves** IV, 527
- **Cylinders, pattern for** II, 126
- **Cylinders and cones**
  - **connected by belts** IV, 486
  - **revolving in contact** IV, 483
- **Cylindrical cams** IV, 511
- **Deflection of shafts** II, 261
- **De Laval steam turbine** III, 330, 351
- **Design**
  - **method of** II, 162
  - **original** II, 222
  - **theoretical** II, 164
- **Detectors, ground** III, 499
- **Diametral pitch** IV, 525
- **Diamond point chisel** I, 40
- **Die forging** IV, 97
- **Die holders** I, 288
- **Dies** I, 65
  - **adjustable** I, 284
  - **sectional** I, 370
  - **spring screw-threading** I, 287
  - **thread cutting** I, 281
- **Diesel cycle** III, 82
- **Differentially-wound motors** III, 398
- **Direct-current dynamos in parallel** III, 384
- **Direct-current 3-wire system** III, 495

Part Page

- **Disc crank, pattern for** II, 112
- **Disconnecting and reversing mechanisms** IV, 495
- **Disk and roller** IV, 493
- **Distribution of illumination** III, 529
- **Dividers** IV, 335
- **Dividers and trammels** II, 39
- **Docks** I, 419
- **Dowel pins** II, 85
- **Drafts, allowance for in patterns** II, 72
- **Drawing, assembly** IV, 403
- **Drawing board** IV, 325
- **Drawing paper** IV, 323
- **Drawing pen** IV, 336
- **Drawings, cost of producing** IV, 416
- **Drill jigs** I, 342, 357
  - **fastening devices for** I, 357
- **Drill press** I, 123
- **Drilling hard metals** I, 197
- **Drilling in the lathe** I, 122
- **Drills** I, 50, 222
  - **chuck** I, 51
  - **flat** I, 51, 222
  - **grinding of** I, 54
  - **lubrication of** I, 53
  - **radial** I, 127
  - **single lip** I, 225
  - **speed of** I, 54
  - **straightway** I, 225
  - **twist** I 51, 228
- **Driving gears for hoists** II, 178
- **Drop forges** IV, 99
- **Drum for hoists** II, 203
- **Drum shaft** II, 189
- **Dry sand work** II, 450
- **Duplex milling machine** I, 167
- **Duplex pump plates** IV, 419
  - **dimensions and letters** IV, 431
  - **foundation** IV, 465
  - **general drawing** IV, 465
  - **order sheets** IV, 469
  - **piston rod and valve stem** IV, 441
  - **plunger and valve details** IV, 463
  - **steam chest and valve** IV, 443
  - **steam cylinder** IV, 427
  - **steam end layout** IV, 421
  - **valve motion details** IV, 451

Note.—For page numbers see foot of pages.

Part Page

Duplex Pump Plates
- valve motion layout IV, 447
- water cylinder IV, 459
- water end layout IV, 455
- yoke, stuffing boxes, brackets, etc. IV, 453

Dynamo
- belts for III, 478
- care of III, 477
- fails to generate III, 464
- installing of III, 473
- name-plates III, 474
- starting up III, 479
- testing for polarity III, 480
- waterproof covers for III, 474
- wiring from III, 474

Dynamo-electric machinery III, 357-471
Dynamo frames, grounding III, 473
Dynamos on three-wire system III, 393
Dynamotors III, 400
Eccentric IV, 518
Eccentric arbors I, 259
Eccentric turning I, 107
Economy coils III, 537
Economy of high-speed steel I, 449-454
Elbow, pattern of II, 121
Electric elevators III, 201
Electric heaters III, 537
Electric ignition III, 43
Electric lifting magnets I, 521-524
Electric lighting I, 463
Electric motors in machine shops I, 475-505
- different makes of apparatus I, 503
- motor-drive systems I, 491
- shop requirements I, 479

Electric welder IV, 108
- adjustments IV, 113
- applications IV, 109

Electric welding
- development IV, 107-116
- joints IV, 115

Electric wiring III, 473-538
Electrical inspection III, 538
Electrical resistance III, 417
Electro-magnetic circuit-breakers III, 375
Elevator III, 177-226

Part Page

Elevator
- accessories of III, 214
- air cushions III, 225
- cables III, 222
- early steam III, 177
- electric III, 201
- electric limit switches for III, 211
- horizontal hydraulic III, 186
- limit valves III, 199
- packing and lubrication for III, 196
- vertical hydraulic III, 191
- water balance III, 185

Emery cloth I, 48
Enclosed fuse III, 533
End mills I, 157, 335
Engine lathe I, 74
Engines
- Corliss III, 294
- gas III, 17
- steam III, 263

Entrance wires III, 493
Epicycloidal curves IV, 529
Erasers, for mechanical drawing IV, 326
Excessive heating in generator III, 448
Exhaust gas engine III, 59
Explosive mixture III, 58
External combustion motor III, 11
Extraction of copper II, 371
Face milling cutters I, 338
Face plate II, 117
Facing tool with inserted cutter I, 293
Field magnets, heating of III, 452
File I, 43
Fillets II, 114
Finish, allowance for in pattern II, 74
Fitting brasses I, 199
Fixed gauges I, 33
Fixture wiring III, 519
Flanges, pattern for II, 125
Flanging iron and steel plates III, 243
Flanging press IV, 101
Flat chisel I, 39
Flat drill I, 51, 222
Flaws in castings I, 507
Flush switches III, 519
Fluted chucking reamers I, 239
Fluted hand reamer I, 235

Note.—For page numbers see foot of pages.

Part Page

- Flutes, forms of I, 267
- Fluting rollers I, 201
- Fluxes IV, 23
  - sand and borax IV, 23
- Fly cutter I, 333
- Fly wheel III, 305
  - weight of III, 310
- Foot lever II, 209
- Forge fire IV, 20
  - fuel for IV, 20
- Forge shop equipment IV, 12
  - anvils IV, 15
  - blast IV, 14
  - flatters IV, 18
  - forge IV, 12
  - fullers IV, 19
  - hammers IV, 14
  - set hammers IV, 18
  - sledges IV, 15
  - swages IV, 18
  - tongs IV, 16
- Forge stock IV, 21
- Forging IV, 11-106
  - crank shafts IV, 58
  - cranks IV, 60
  - finish of IV, 56
  - furnaces for IV, 102
  - knuckles IV, 64
  - ladle shank IV, 68
  - lever with boss IV, 62
  - manufacturing shop IV, 99
  - materials IV, 11
  - molder's trowel IV, 68
  - socket wrenches IV, 69
  - weight of IV, 55
  - weldless rings IV, 61
  - wrenches IV, 64
- Forging, heavy
  - connecting rod IV, 91
  - crank shafts IV, 90
  - hammer chisels IV, 88
  - hammer dies IV, 87
  - steam hammer IV, 86
  - tongs IV, 88
  - tools, tapering IV, 89
- Forging, simple IV, 41
  - bolt tongs IV, 51

Part Page

- Forging
  - bolts IV, 46
  - chain hooks IV, 44
  - eye bolts IV, 43
  - forming shoulders IV, 42
  - hoisting hooks IV, 45
  - ladles IV, 51
  - light tongs IV, 50
  - pick-up tongs IV, 51
  - tongs IV, 49
  - twisted gate hook IV, 41
  - upset head bolts IV, 47
  - welded head bolts IV, 48
- Forging operations IV, 34
  - bend with square forged corner IV, 40
  - drawing out IV, 35
  - finishing IV, 35
  - punching IV, 38
  - ring and eye bending IV, 39
  - shaping IV, 34
  - truing up work IV, 36
  - upsetting IV, 37
- Forging tools IV, 19
- Formed cutters I, 155, 325
- Formed reamers I, 250
- Forming die I, 384
- Forming tools I, 303
  - circular I, 305
- Foundry facings II, 392
- Foundry ladles II, 477
- Foundry tools II, 395
- Foundry work II, 387-529
- Friction of bearings III, 410
- Friction and lubrication of metals II, 171
- Friction clutches II, 293; IV, 496
  - problems on II, 299
- Fuel for foundry II, 485
- Fuel to iron II, 486
- Furnace flues III, 259
- Furnace hoists II, 538
- Furnaces
  - blast II, 339
  - for lead smelting II, 376
  - natural draft II, 514
  - reverberatory IV, 103
- Fuse terminals III 531

Note.—For page numbers see foot of pages.

Part Page

- Fuse wires III, 532
- Fuses III, 531
- Gang die I, 379
- Gas engines III, 11-85
  - care of III, 71
  - Charter III, 23
  - exhaust III, 59
  - fuel consumption III, 74
  - fuels III, 65
  - governing of III, 47
  - ignition of III, 41
  - modern III, 17
  - Nash III, 21
  - Olds III, 22
  - rapid development of III, 73
  - starting III, 53
  - water jacket III, 57
  - Westinghouse III, 18
- Gas producer II, 365
- Gases, utilization of I, 425
- Gasoline engines III, 76
- Gating II, 407
- Gauge making I, 386
- Gauges
  - fixed I, 33
  - limit I, 35, 403
  - locating I, 408
  - plug I, 388
  - receiving I, 404
  - ring I, 391
  - snap I, 395
- Gear design data II, 280
- Gear guard II, 209
- Gearing IV, 524
- Gears
  - annular IV, 529
  - bevel II, 280; IV, 531
  - cutting of I, 182
  - hook teeth II, 278
  - for hoists II, 195
  - mortise teeth II, 277
  - problems on II, 291
  - rack and pinion IV, 529
  - shrouding tooth II, 277
  - spur II, 268; IV, 524
- Generator
  - circuit breakers for III, 474

Part Page

- Generator
  - constant-current III, 409
  - directions for running III, 407
  - efficiency of III, 431
  - fuses for III, 474
  - in parallel III, 384
  - power of III, 430
  - separation of losses III, 432
  - in series III, 391
  - starting of III, 382
  - stopping III, 409
  - torque of III, 430
- Globe valve
  - pattern for II, 133
  - stuffing box pattern II, 138
  - template for II, 134
- Glue, preparation of II, 88
- Gluing II, 88
- Gouges and chisels II, 31
- Governing of engine III, 47
  - hit-and-miss system III, 48
  - variable impulse system III, 49
- Governors
  - Buckeye engine III, 320
  - shaft III, 319
  - spring III, 319
  - steam engine III, 312
  - straight-line engine III, 321
- Grab buckets II, 535
- Grinding drills I, 54
- Grinding hole to size I, 312
- Grinding machine I, 184
- Grinding teeth on milling cutter I, 314
- Grinding valves I, 197
- Grindstones II, 50
- Ground detectors III, 499
- Grounding dynamo frames III, 473
- Guard arms III, 493
- Guard irons III, 503
- Hammer II, 42
- Hammer break contact III, 44
- Hand-operated tools I, 11
  - bevel I, 16
  - center punch I, 12
  - center square I, 17
  - crosscut saw II, 17
  - protractor I, 17

Note.—For page numbers see foot of pages.

Part Page
Hand-operated tools
  rip saw II, 17
  saws II, 17
  scriber I. 13
  straight edge I. 14
  surface gauge I 13
  try square I, 15
Hand taps I, 265
Hand wheel, pattern for II, 95
Handbooks for machine design II. 159
Hanger-boards III, 537
Hardening reamers I. 237
Harvey process for making armor II. 368
Heating of armature III, 451
Heating of bearings III, 453
Heating of commutator and brushes III, 449
Heating of field magnets III, 452
Helix IV, 497
Hematite II. 339
High speed engines III. 281
High-speed steel
  economy of I, 449
  test of results I, 452
Hoists, design of
  bearings, length of II, 184
  brackets and caps II, 199
  brake for II, 203
  brake-relief spring II. 209
  driving gears II, 178
  drum and brake II, 203
  foot lever II, 209
  gear guard II, 209
  gears II, 195
  preliminary layout II, 191
  preliminary sketch II, 178
  pulleys II, 181, 193
  rope and drum II, 178
  shafts for II, 184
  width of belt for II, 183
Hoists, furnace II, 538
Holding work on planer I, 137
Hollow mills I, 299
  adjustable I, 300
  with inserted blades I, 301
  with pilot I, 302
Hollow shafts II, 267

Part Page
Hook teeth gears II, 278
Horizontal milling machine I, 102
Horse-power
  of belting II, 235
  of shafts II, 264
Hubs II, 109
Hulett unloader II, 537
Ideal foreman I, 533-538
Igniter, make-and-break III, 44
Igniter gear III, 45
Ignition of gas engine III, 41
Illumination brilliancy of III, 528
Incandescent lamps III, 526
  in series circuits III, 533
Indicator, Watt's III, 268
Igintion, electric III, 43
Induction motor
  single-phase III, 406
  speed regulation of III, 405
Ingots II, 359
  pouring, methods of II, 359
  shape of II, 360
Ink used in drawing IV, 338
Inserted blade reamers I, 244
Inserted blade taps I, 273
Inserted-tooth cutter I, 155
Inside wiring III, 505
Installation of motors III, 484
Insulated metal conduits III, 516
Insulating joints III, 524
Insulation resistance III, 525
  testing of III, 477
  voltmeter test for III, 422
Insulations, cleaning of III, 482
Intensity of illumination III, 528
Interior conduit installation III, 517
Internal combustion motor III, 12
  history of III, 14
Invention—relation of machine design II, 159
Involute curves IV, 529
Iron II, 337
  casting of I, 427
  chemistry of II, 481
  manufacture of I, 411-429
  melting of II, 485
  moulding of II, 387

Note.—For page numbers see foot of pages.

Part Page

- Iron
  - ores of II, 337
  - shrinking of IV, 91
  - surface mining of I, 418
  - temperatures of IV, 106
- Iron moulding II, 387
- Iron ore II, 337
  - hematite II, 339
  - limonite II, 339
  - magnetite II, 339
  - siderite II, 341
- Irregular curve IV, 340
- Jaw clutch IV, 495
- Jet condenser III, 300
- Joints I, 199
  - insulating III, 524
- Jump spark method of ignition III, 46
- Kerosene and crude oil engines III, 79
- Keys, machine II, 314
- Knife switches III, 525
- Ladles for casting II, 359, 477
- Lamps
  - arrangement of III, 529
  - automobile III, 172
  - incandescent III, 526
- Lap weld IV, 25
- Lapping a gauge to size I, 400
- Lathe I, 71; II, 51
  - engine I, 74
  - size of I, 78
  - speed I, 72
- Lathe chuck, pattern for II, 123
- Lathe dogs I, 83
- Lathe tools I, 91; II, 54
- Lead II, 375
  - desilverized, refining II, 377
  - properties of II, 379
  - smelting II, 376
- Leather belting
  - sizes of, table II, 238
  - strength of II, 235
- Lenoir engine III, 14
- Levers IV, 512
- Light, Cooper Hewitt I, 466
- Light and power wiring III, 511
- Lighting
  - artificial I, 461

Part Page

- Lighting
  - electric I, 463
- Lightning arresters III, 476
- Limit gauges I, 35, 403
- Limit switches III, 375
- Limit valves, elevator III, 199
- Limonite II, 339
- Line wires III, 490
- Linear velocity IV, 481
- Lines, mechanical drawing IV, 370
- Lining shafting I, 202
- Link work IV, 514
  - crank and connecting rod IV, 516
  - eccentric IV, 518
  - four-bar linkage IV, 514
- Lipe tool post I, 95
- Loam II, 453
- Loam cores II, 453
- Loam moulds II, 457
- Loam work II, 388
- Locating faults
  - direct-deflection method III, 421
  - drop method III, 419
- Locating gauge I, 408
- Lock nuts II, 311
- Locomotive engines III, 288
- Low-potential circuits, grounding of III, 495
- Lubricants III, 324
- Lubrication III, 322
- Lubricators, sight feed III, 326
- Machine
  - assembling of III, 369
  - bearings of III, 479
  - belting for III, 362
  - direct connection III, 361
  - examination of III, 382
  - fixing III, 360
  - heating III, 412
  - hot box III, 483
  - inspecting III, 410
  - mechanical conditions III, 358
  - mechanical connections III, 360
  - noise of III, 412
  - oily waste of III, 483
  - selection of III, 357
  - speed of III, 428

Note.—For page numbers see foot of pages.

	Part	Page
Machine		
testing	III,	410
torque of	III,	429
Machine, definition of	IV,	475
Machine brackets	II,	324
Machine cotters	II,	320
Machine design	II,	155-335
bearings	II,	324
belts	II,	329
bevel gears	II,	280
bolts, etc.	II,	303
brackets	II,	324
brackets and caps	II,	199
calculations and notes	II,	160
commercial aspect	II,	158
cotters	II,	320
couplings	II,	299
definition of	II,	155
delineation and specification	II,	166
drum and brake	II,	203
empirical data for	II,	159
foot lever	II,	209
formulas, general	II,	169
friction clutches	II,	293
friction and lubrication	II,	171
handbooks for	II,	159
keys, pins, etc.	II,	314
method of	II,	162
modification	II,	165
practical care	II,	175
practical modification	II,	165
problems	II,	177
pulleys	II,	240
shafts	II,	254
split pulleys	II,	248
spur gears	II,	268
stresses and strains	II,	172
summary	II,	226
theoretical	II,	164
theory	II,	157
torsional moments	II,	183
worm gears	II,	286
Machine screws	II,	313
Machine setting	I,	203
Machine shop work	I,	11-205
laying out work	I,	192
shop suggestions	I,	196

	Part	Page
Machine taps	I,	270
Machine tools	II,	215
Machinery	II,	214
mill and plant	II,	221
motive-power	II,	217
structural	II,	218
Machinist, making a	I,	513-520
Machinist's bench	I,	38
Magnetic clutches	I,	527-530
Magnets, electric lifting	I,	521-524
Magnetite	II,	339
Making a machinist	I,	513-520
Malleable cast iron	II,	346
Mandrels	I,	84, 252
expanding	I,	257
Manganese	II,	346
Manufacture of iron	I,	411
ingredients used in	I,	415
Manufacture of steel	I,	431-446
processes used in	I,	432
Bessemer	I,	442
crucible	I,	432
open hearth	I,	435
Marine engines	III,	287
Marking gauges	II,	38
Materials for		
blast furnace	II,	341
forging	IV,	11
pattern making	II,	12
Measuring tools	I,	18
caliper	I,	21
caliper square	I,	23
micrometer caliper	I,	24
retrograde Vernier	I,	32
standard steel scale	I,	16
transfer calipers	I,	22
Vernier	I,	27
wing dividers	I,	20
Mechanical conditions for machinery	III,	358
Mechanical drawing	IV,	323-474
assembly drawing	IV,	403
blue printing	IV,	402
bolts and nuts	IV,	388
conventional methods	IV,	382
cross-sections	IV,	373
detail drawing	IV,	399

Note.—For page numbers see foot of pages.

Part Page
Mechanical drawing
  dimensions IV, 378, 431
  finished surfaces IV, 381
  instruments IV, 323
  invisible threads IV, 384
  lines IV, 370
  location of views IV, 371
  long pieces IV, 397
  materials IV, 323
  plan and scope of advanced work IV, 413
  pipes and pipe threads IV, 394
  projections IV, 347
  scale drawings IV, 395
  screw threads IV, 383
  shade lines IV, 375
  sketches IV, 398
  threads in sectional pieces IV, 386
  threaded holes IV, 384
  tracing IV, 401
  "turning up" a section IV, 398
  utility of IV, 413
  working drawings IV, 369, 413
Mechanics, constructive II, 168
Mechanism IV, 475-531
  definition of IV, 475
  disconnecting and reversing IV, 495
  gearing IV, 524
  link work IV, 514
  machine IV, 475
  motion IV, 475
  revolving bodies IV, 480
  velocity IV, 476
  worm and wheel IV, 504
Melting
  principles of II, 485
  iron II, 485
  metal II, 470
  steel II, 500
Metal II, 383
  melting of II 470
  pouring of II, 479
Metal patterns II, 110
Metallurgy II, 337-385
  alloys II, 384
  aluminum II, 381
  copper, properties of II, 371, 504

Part Page
Metallurgy
  desilverized lead, refining II, 377
  lead II, 375
  lead smelting II, 376
  lead softening and desilverizing II, 379
  silver and gold, from lead II, 378
  table of alloys II, 385
  table of metals II, 383
  tin II, 379, 504
  zinc II, 380, 505
Micrometer, reading I, 26
Micrometer caliper I, 24
Micrometer graduations I, 162
Mill and plant machinery II, 221
Milling cutters I, 309
  arbors for I, 340
  with interlocking teeth I, 318
  spiral I, 315
Milling machine I, 149
  duplex I, 167
  horizontal I, 162
  universal I, 164
  vertical I, 469-474
Minerals II, 339
Mortise teeth gears II, 277
Motion IV, 475
  absolute and relative IV, 475
  composite IV, 477
  direction of IV, 476
  quick return IV, 521
  revolving bodies IV, 480
Motive-power machinery II, 217
Motor
  automobile III, 97
  external combustion III, 11
  failure to start III, 461
  induction III, 405
  internal combustion III, 12
  stopping III, 461
Motor wiring formulae III, 487
Motors III, 393
  alternating-current III, 400
  compound-wound III, 398
  constant-potential III, 409
  differentially-wound III, 398
  directions for running III, 407

Note.—For page numbers see foot of pages.

	Part	Page
Motors		
installation of	III,	484
series-wound	III,	396
shunt-wound	III,	394
starting induction	III,	403
stopping	III,	409
Moulding		
iron	II,	387
materials for	II,	389, 507
methods of	II,	63
principles of	II,	402
problems of	II,	414
tools for	II,	395
Moulding machines	II,	445
Moulds	II,	359
blacking for	II,	433
building	II,	465
packing of	II,	498
pressure in	II,	411
Multiple die	I,	382
Multiple-throw cranks	IV	60
Nash gas engine	III,	21
Newcomen steam engine	III,	265
Nicked teeth spiral cutters	I	321
Nickel steel	II,	366
Noisy operation of machinery	III,	456
Nuts	II,	303
lock	II,	311
problems on	II,	313
Oil consumption	III,	85
Oil engines	III,	75
care of	III,	84
fuel for	III,	75
Oil stones	II,	48
Olds gas engine	III,	22
Open hearth steel process	I,	435
Operation of blast furnace	II,	341
Order sheets, Duplex pump	IV,	469
Ores, copper	II,	371
Ores, preparation of	II,	339
Ores of iron	II,	337, 371
Orthographic projections	IV,	347
Otto cycle	III,	16
ideal and real	III,	38
with increased expansion	III,	38
modifications of	III,	60
thermodynamics of	III,	27

	Part	Page
Pack hardening	I,	219
Parsons steam turbine	III,	333
Pattern maker, qualifications of	II,	11
Pattern making	II,	11-154
bevel gears	II,	149
column	II,	152
dowel pins	II,	85
draft	II,	72
engine cylinder	II,	129
face plate	II,	117
fillets	II,	114
finish	II,	74
follow boards	II,	153
gear wheel	II,	139
globe valve	II,	133
glue for	II,	88
gluing	II,	88
hand screws	II,	90
hubs	II,	109
moulding, methods of	II,	63
pipe connections	II,	119
planes	II,	23
rapping plates	II,	110
shrinkage	II,	72
tools for	II,	17
wood for	II,	12
Patterns		
built up	II,	91-108
cylinders	II,	126
disc crank	II,	112
from drawings	II,	71
elbow	II,	121
finishing of	II,	81
flanges	II,	125
of hand wheel	II,	95
lathe chuck	II,	123
materials for	II,	12
metal	II,	110
return bend	II,	123
of sheave pulley	II,	91
simple	II,	77
tee	II,	119
Pencils, drawing	IV,	326
Pening	I,	196
Personal safety	III,	408
Petticoat insulators	III,	493
Phosphorus, effect on iron	II,	345, 506

Note.—For page numbers see foot of pages.

Part Page
- Pickling castings I, 201
- Pinion bore for hoists II, 189
- Pinion shaft outer bearing II, 189
- Pins, machine II, 314
- Pipe bending IV, 95
- Pipe connections, pattern for II, 119
- Pipe threads, cutting I, 66
- Pitch IV, 525
- Plain milling cutter I, 157
- Planer I, 133
- Planer tools I, 137
- Planes
  - holding work on II, 29
  - iron II, 23
  - pattern maker II, 23
  - rabbet II, 27
  - router II, 30
  - round and hollow II, 28
- Planing machines, wood II, 60
- Plate cams IV 507
- Plate planer I, 139
- Pliers II, 44
- Plug gauge I, 388
- Poles
  - guying of III, 505
  - holes for III, 501
  - painting of III, 503
  - primary wires on III, 505
  - setting of III, 501
  - steps of III, 503
- Poles for light and power wires III, 500
- Polyphase systems II, 304
- Power hammers IV, 100
- Presses IV, 101
- Pressures and temperatures III, 29
- Primary wiring III, 500
- Producer plants III, 68
- Profile plane projections IV, 353
- Projections
  - orthographic IV, 347
  - profile plane IV, 353
- Protractor 17; IV, 339
- Puddling process II, 347
- Pulley arm II 109, 243
- Pulley bores for hoists II, 185
- Pulley hubs II, 245

Part Page
- Pulley rim II, 241
- Pulleys
  - analysis of II, 240
  - crowning IV, 488
  - design of II, 240
  - for hoists II, 193
  - moulding II, 446
  - practical modification of II, 246
  - problems on II, 253
  - special forms of II, 252
  - split II, 248
  - theory of II, 241
  - tight and loose IV, 495
- Pumping engines III, 290
- Pumps, automobile III, 160
- Punch I, 374
  - hardening of I, 376
- Punch and die, fit of I, 375
- Punch and die work I, 364
- Rabbet plane II, 27
- Rack and pinion gears IV, 529
- Radial drill I, 127
- Rail making II, 361
- Ramming II, 404
- Rapping plates II, 110
- Reamer holders I, 252
- Reamers I, 58, 234
  - adjustable I, 245
  - formed I, 250
  - hardening I, 237
  - inserted blade I, 244
  - shell I, 248
  - straightening I, 238
  - taper I, 247
- Receiving gauge I, 404
- Refining of copper II, 373
- Releasing tap holders I, 277
- Removable bushings I, 360
- Retrograde vernier I, 32
- Return bend, pattern for II, 123
- Reverberatory furnace IV, 103
- Ring gauge I, 391
- Ring round stock IV, 27
- Rivets and riveting III, 238
- Roof structures III, 493
- Rope driving III, 366
- Rope and drum for hoists II, 178

Part Page
Rose reamers I, 240
Rosettes, location of III, 519
Round and hollow planes II, 28
Router plane II, 30
Rule, pattern maker II, 46
Safety fuses III, 374
Sand mixing II, 487
Sands, molding II, 389, 487
Savery steam engine III, 263
Sawing machines II, 56
Saws II, 59
  back II, 21
  band II, 59
  compass II, 22
  crosscut II, 17
  rip II, 17
  scroll II, 59
Scale I, 201
Scales, drawing IV, 339
Scarfing IV, 24
Scavenging III, 60
Scraping I, 49
Scratch awl I, 13; II, 43
Screw cutting tools I, 112
Screw die hobs I, 271
Screw-driver II, 43
Screw threads I, 113
  drawing of IV, 383
Screws II, 303; IV, 497
  combination of IV, 502
  machine II, 313
  set II, 312
Scriber I, 13
Sectional dies I, 370
Series-wound direct-current dynamos in series III, 392
Series-wound dynamos III, 385
Series-wound motors III, 396
Service blocks III, 493
Service wires III, 490
Set screws II, 312
Shade lines, mechanical drawing IV, 375
Shaft outside of pinion II, 189
Shafting III, 368
Shafts II, 254
  analysis of II, 254

Part Page
Shafts
  centrifugal whirling II, 263
  deflection II, 261
  hollow II, 267
  horse-power of II, 264
  material for II, 267
  practical modification II, 265
  problems on II, 268
  size of II, 184
  theory of II, 257
Shaper I, 141
Sheave pulley, pattern for II, 91
Sheet-metal work IV, 119-263
  approximate developments IV, 138
  construction IV, 119
  developments by triangulation IV, 131
  intersections and developments IV, 121-130
  patterns IV, 121
  practical workshop problems IV, 142
  shop tools IV, 120
  tables IV, 120
Shell end mills I, 160
Shell reamers I, 248
  arbors for I, 250
Shop drawing IV, 413
  essentials IV, 415
  method of procedure IV, 418
Shop lighting I, 457-466
  artificial I, 461
  distribution of sunlight I, 459
  electric I, 463
Shrinkage, allowance for in patterns II, 72
Shrinkage heads II, 410
Shrouding tooth gears II, 277
Shunt or compound dynamos in series III, 392
Shunt dynamo III, 378
Shunt-wound motors III, 394
Side milling cutter I, 153
Siderite II, 341
Silicon, effect on iron II, 345
Single lip drill I, 225
Single lip reamer I, 242
Single-phase induction motor III, 406

Note.—For page numbers see foot of pages.

Part Page
Slabbing miller I, 165
Slag II, 343
Sledges IV, 15
Slotter I, 143
Smelting, cupola II, 372
Smelting lead II, 376
Snap gauge I, 395
    for cylindrical work I, 396
    grinding of I, 398
Snap switches III, 526
Spark coil III, 43
Sparking at commutator III. 413, 440-448
Special lamp sockets III, 521
Special tools I, 211
Special wiring III, 514
Speed too high or too low III, 460
Speed lathe I, 72
Speed regulation of induction motor III, 405
Spiral milling cutters I, 315
Spiral teeth cutters I, 152
Spirals I, 180
Splicing of wire III, 498, 507
Spline II, 315
Splining shafts I, 175
Split pulley design II, 248
    analysis and theory of IV, 248
    practical modification II, 252
Spoke-shave II, 30
Spring screw threading dies I, 287
Spring tempering steel I, 222
Sprue cutter II, 512
Spur gears II 268; IV, 524
    analysis II, 269
    arms II, 275
    hub II, 275
    rim II, 275
    theory II, 272
    working stress for II, 274
Square thread taps I, 275
Squares II, 34
Standard key ways I, 325
Standard lamp sockets III, 521
Standard screw threads I, 114
Standard steel scale I, 19
Standard taper for drill shanks I. 52
Stands, machine II, 324

Part Page
Starting-boxes III, 376
Starting gas engine III 58
Steady rest I, 79
Steam cylinder, Duplex pump IV, 437
Steam engine III, 263-335
    Corliss III, 294
    Cornish III, 271
    cylinder ratios III, 279
    governors III, 312
    high speed III, 281
    locomotive III, 286
    marine III, 287
    Newcomen III, 265
    parts of III, 271
    pumping III, 290
    Savery III, 263
    Stephenson III, 269
    triple expansion III, 279
    types of III, 275
        compound III, 277
        simple III, 276
    vertical and horizontal III, 284
    Watt III, 267
    Woolf III, 279
Steam pumps, direct-acting III, 291
Steam turbine III, 328, 337-354
    applications III, 342
    balance IIIi 339
    clearances III, 338
    condensers III, 340
    De Laval III. 330, 351
    governing III, 340
    Parsons III, 333
    pressures and superheat III, 342
    step-bearing III, 338
    vertical type III, 338
    wear on buckets III, 342
    Westinghouse-Parsons III, 346
Steel
    aluminum II, 367
    castings II, 495
    cementation II, 350
    chrome II, 367
    definition of I, 431
    effects of elements in II, 369
    manganese II, 367
    manufacture of I, 431-446; II. 351

Note.—For page numbers see foot of pages.

Part Page

- Steel, manufacture of
    - Bessemer process II, 354
    - cementation process II, 351
    - crucible process II, 353
    - cupola process II, 356
    - direct process II, 356
    - open hearth process II, 362
  - melting of II, 500
  - nickel II, 366
  - self-hardening IV, 85
    - Taylor-White process IV, 85
  - special II, 366
  - tempering of II, 369
  - tool I, 213
  - tungsten I, 449; II, 368
- Steel castings II, 495
- Steel cores II, 499
- Steel facing mixtures II, 496
- Steel flasks II, 497
- Steel molds II, 502
- Steel rails II, 361
- Stephenson link motion III, 270
- Stephenson steam engine III, 269
- Stepped cones IV, 492
- Storage batteries III 477
- Straight edge I, 14
- Straight reamers
  - fluted chucking I, 239
  - fluted hand I, 235
  - rose I, 240
  - single lip I, 242
  - three lipped roughing I, 243
- Straightening reamers I, 238
- Straightway drills I, 225
- Stranded wires III, 522
- Stresses
  - combined in shaft II, 257
  - working II, 172
- Structural machinery II, 218
- Studs II 303, 312
- Sulphur, effect on iron II, 345
- Sunlight, distribution of I, 459
- Surface condenser III 297
- Surface gauge I, 13
- Surface mining of iron I, 418
- Swage blocks IV, 19
- Switchboard III, 475

Part Page

- Switches III 372
  - flush III, 525
  - knife III, 525
  - limit III, 375
- Synchronism III, 389
- T-slot cutter I, 337
- T-square IV, 327
- T-weld IV, 31
- Tables
  - alloys II, 385
  - amperes per motor III, 488
  - angles and tees IV, 190
  - bolts strength of II, 308
  - cast iron, grades of II, 345
  - cast iron—end or face milling of I, 172
  - cast iron, surface milling of I, 172
  - cedar poles for electric work III 503
  - chisels and gouges II, 31
  - clearance on efficiency, effect of III 37
  - cupola furnaces II, 473
  - cutting edges for milling cutters I, 310
  - cutting edges for reamers I, 235
  - dimensions of enclosed fuses III, 534
  - dimensions and resistances of copper wire III, 512
  - drills, speed of I, 57
  - face milling cutters I, 340
  - foundry ladles II, 478
  - gear design data II, 280
  - grinding wheels, speed of I, 187
  - hexagon bolt heads IV, 393
  - incandescent lamp data III, 527
  - machines for different circuits III, 377
  - mandrel dimensions I, 256
  - metals II, 383
  - minimum break distance III, 531
  - number of cutters for reamers I, 236
  - pig irons, analysis of I, 429
  - pole line data III, 504
  - pressure in molds II, 529
  - requisite thickness of rubber covering for wires III, 506
  - rivet dimensions III 238
  - riveted joints strengths III, 242

Note.—For page numbers see foot of pages.

Part Page
Tables
  safe carrying capacity of copper wires III, 371
  self-carrying capacity of wires III, 507
  shafting III, 368
  sheet copper IV, 179
  sheet zinc IV, 180
  shell reamer dimensions I, 248
  sizes of leather belting II, 238
  soft machinery steel I, 172, 173
  speed of engine III, 316
  spring screw-threading dies I, 287
  square bolt heads IV, 393
  square and hexagon nuts IV, 393
  square and round iron bars IV, 188-189
  standard gauge for sheet iron and steel IV, 181
  standard key ways for cutters I, 326
  switch data III, 373
  taps and drills I, 63
  tested fuse wire III, 530
  tin plates standard IV, 308
  torsional moments II, 183
  twist drills, cutting flutes in I, 230
  useful factors II 528
  U. S. standard screw threads I, 115; IV, 387
  volts lost III, 489
  weight of cast iron, etc. IV, 178
  weight of flat rolled iron IV, 56, 182-187
  weight of round and square rolled iron IV 57
  Whitworth standard screw threads IV, 388
  wiring for light and power circuits III, 510
  wrought iron pipe IV, 395
Tachometer III, 428
Tap bolts II, 312
Taper cones IV, 490
Taper key II, 316
Taper reamers I, 247

Part Page
Taper taps I, 270
Taps I, 61, 263
  adjustable I, 272
  hardening I, 269
  inserted blade I, 273
  machine I, 270
  square thread I, 275
  taper I, 270
Tee, pattern for II, 119
Telegraph and telephone wires III, 493
Tempering steel I, 220
Temperatures and pressures III, 29
Templets I, 68
Terminals, fuse III, 531
Testing of insulation resistance III, 477
Thermodynamics of Otto cycle III, 27
Thread cutting dies I, 281
Threaded holes in milling cutters I, 332
Three lipped roughing reamers I, 243
Three-throw cranks IV, 61
Through bolts II, 312
Thumb tacks IV, 325
Tie wires III, 490
Timing valve III, 43
Tin, properties and uses of II, 379
Tinsmithing IV, 271-320
  allowance for seaming and wiring IV, 283
  construction IV, 271
  intersections and developments IV, 272-282
  notching patterns IV, 284
  patterns IV, 272
  practical problems
    colander IV, 306
    drip pan IV, 291
    foot bath IV, 296
    funnel and spout IV, 287
    hand scoop IV, 288
    measure IV, 300
    pail IV, 285
    scale scoop IV, 302
    tea pot IV, 293
    wash boiler IV, 299
  short rules IV, 283
  tools IV, 272

Note.—For page numbers see foot of pages.

Part Page

Tinsmithing
  transferring patterns IV, 285
  workshop problems IV, 283
Tires, automobile III, 150
Tongs for forging IV, 16
Tool forging and tempering
  blacksmith's tools IV, 84
  boring tools IV, 78
  cape chisels IV, 75
  centering tool IV, 81
  cold chisels IV, 74
  cutting off tools IV, 77
  diamond points IV, 78
  finishing tool IV, 81
  flat drills IV, 81
  forging heat IV, 73
  hammers IV, 82
  lathe tools IV, 76
  side tools IV, 79
  springs IV, 81
Tool holders I, 308
Tool making I, 207-410
  points to be observed I, 210
Tool steel I, 213; IV, 70
  annealing I, 214
  hardening I 217; IV, 71
    citric acid bath I, 218
    cooling I, 217
    heating I, 217
  heat treatment for I, 451
  lead bath IV, 73
  pack hardening I, 219
  tempering I 220; IV, 72
  welding of IV, 31
Tools
  bevel II, 37
  boring I, 98
  calipers II, 40
  chasing I, 121
  cutting I, 39
  dividers and trammels II, 39
  hand-operated I 11
  hand saws II, 17
  lathe II, 51
  machine II, 215
  marking gauges II, 38
  measuring I, 18

Part Page

Tools
  pattern making II, 17
  planes, pattern makers II, 23
  planing machine, wood II, 60
  rules II, 46
  sawing machines II, 56
  saws II, 59
  screw cutting I, 112
  special I, 211
  spoke-shave II, 30
  squares II, 34
  turning I, 96
Toothed gearing III, 368
Torque of generator III, 430
Torsional moments, table II, 183
Tracing IV, 401
Trammels and dividers II, 39
Tramways II, 533
Transfer calipers I, 22
Transformers, location of III, 495
Tree wiring III, 493
Triangles IV, 329
Troubles
  localization and remedy of III, 438
  use of table of III, 439
Trowel, molder's IV, 68
Try square I, 15
Tungsten steel I, 449; II, 368
Turning an eccentric I, 108
Turning a taper I, 103
Turning tools I, 96
"Turning up" a section IV, 398
Turning work I, 102
Twist drill I, 51, 228
  grinding I, 234
  hardening I, 232
Uninsulated metal conduits III, 517
Universal milling machine I, 164
Valve gearing III, 26
Vaporization III, 110
Vaporizers, automobile III, 107
Velocity
  definition of IV, 476
  linear IV, 481
Venting II, 406
Venting moulds II, 406
Vernier I, 27

Note.—For page numbers see foot of pages.

	Part	Page
Vernier. reading	I,	30
Vernier micrometer	I,	31
Vertical and horizontal engines	III,	284
Vertical hydraulic elevator	III,	191
Vertical milling machine	I,	469-474
Vertical milling spindle	I,	167
Voltage of generator	III,	470
Voltage of machine	III,	424
Voltmeter test for insulation resistance	III,	422
Warping of wood	II,	14
Water cylinder, Duplex pump	IV,	459
Water gas	III,	65
Water jacket	III	57
Watt steam engine	III	267
Welded joints	III,	243
Welding	IV,	22
allowance for	IV,	27
compounds	IV,	24
electric	IV,	107
tool steel	IV,	31
Welsbach burner	I,	462
Westinghouse gas engine	III	18
Westinghouse Parsons steam turbine	III.	346
Wheatstone bridge	III,	417
Wheels, automobile	III,	149
Wing dividers	I.	20
Wires		
approved "rubber-covered"	III,	505
carrying capacity of	III,	506
fuse	III,	532
installation of	III,	509
line	III,	490
for outside use	III,	500
"slow burning weatherproof"	III,	506
space between	III,	493
stranded	III,	508
"weatherproof"	III,	506
Wiring		
fixture	III,	519
inside	III,	505
light and power	III,	511
methods of	III,	370
Wiring moulding work	III,	514
Wiring table	III,	508
Wiring and construction, outside	III,	490
Wood		
for pattern making	II,	12
warping of	II,	14
"Woodruff" key	II,	183
Woolf steam engine	III,	270
Working stresses and strains	II,	172
Worm gears	II,	216
Worm and wheel mechanism	IV,	504
Wrenches	IV	64
Wrought iron	II,	347
Zinc	II,	380, 505

Note.—For page numbers see foot of pages.

p.7.